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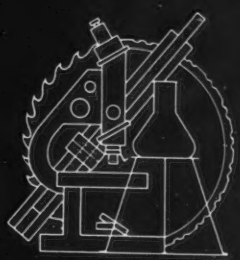

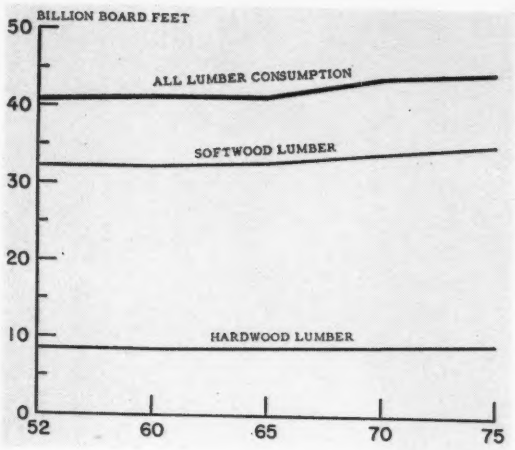

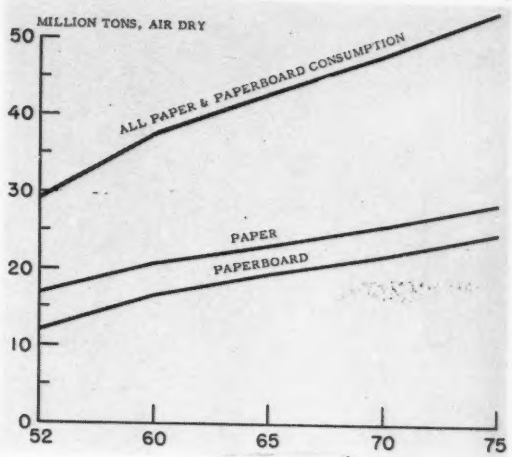

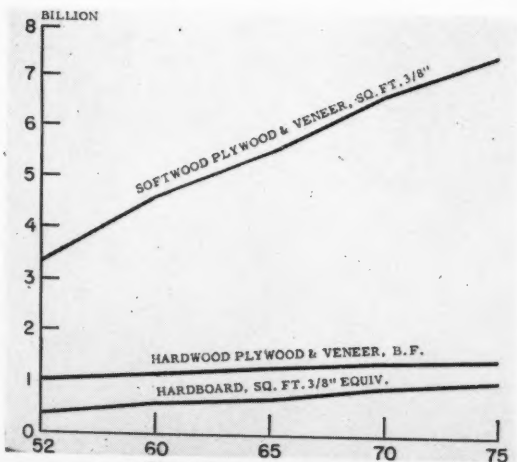

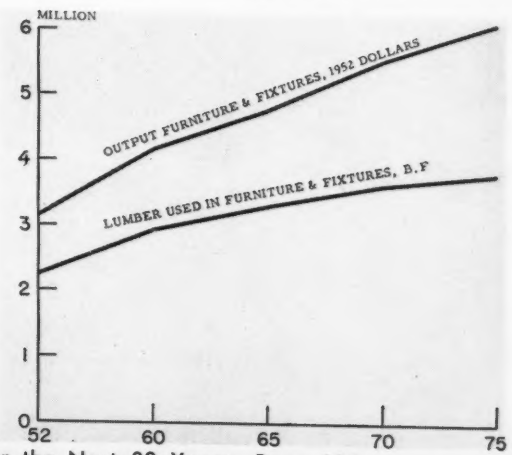

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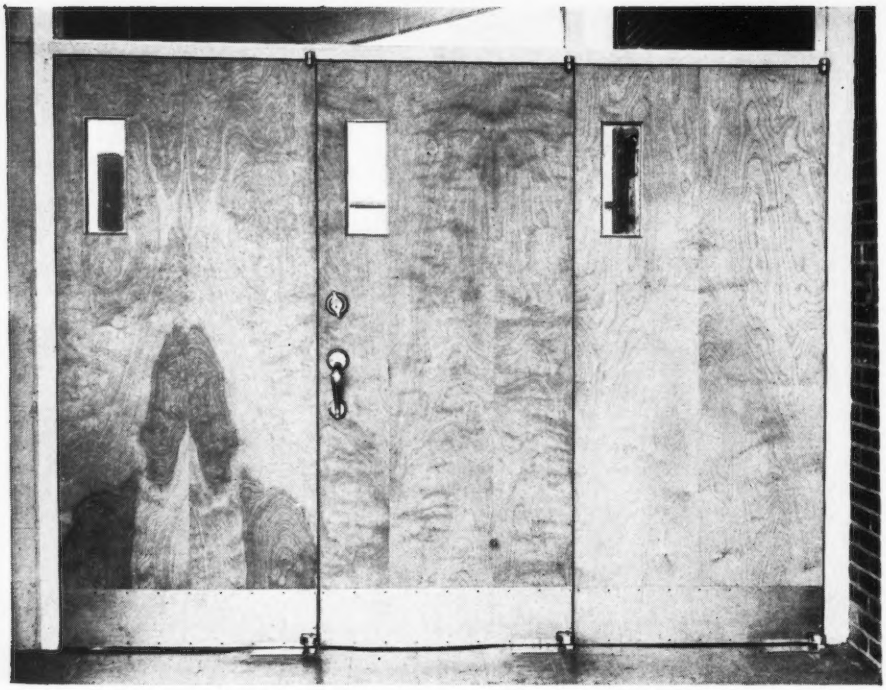

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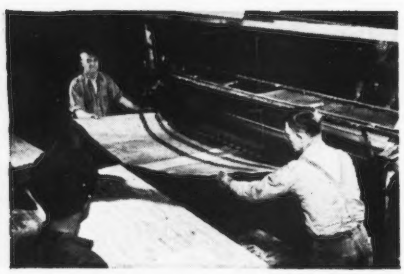

Spread with MELURAC 300, cross-banding emerges from glue spreader ready to be applied to Roddis door core.

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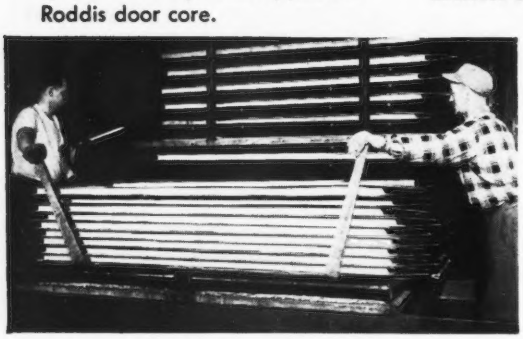

After placing door layups between aluminum caul boards, operators ready automatic press loader. Press accommodates 4' x 8' panels.

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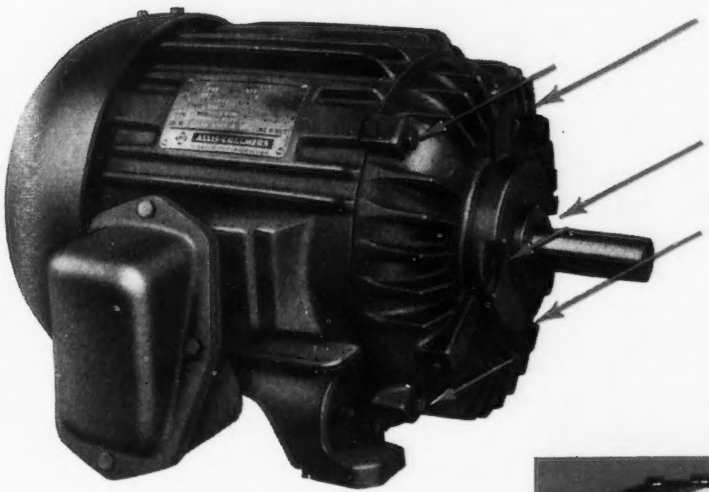

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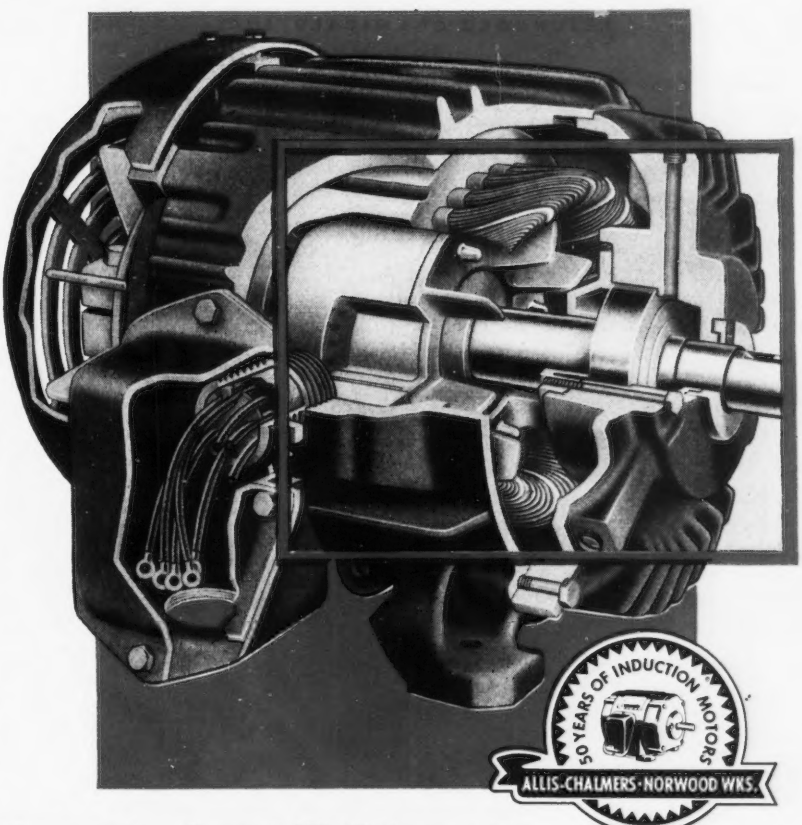

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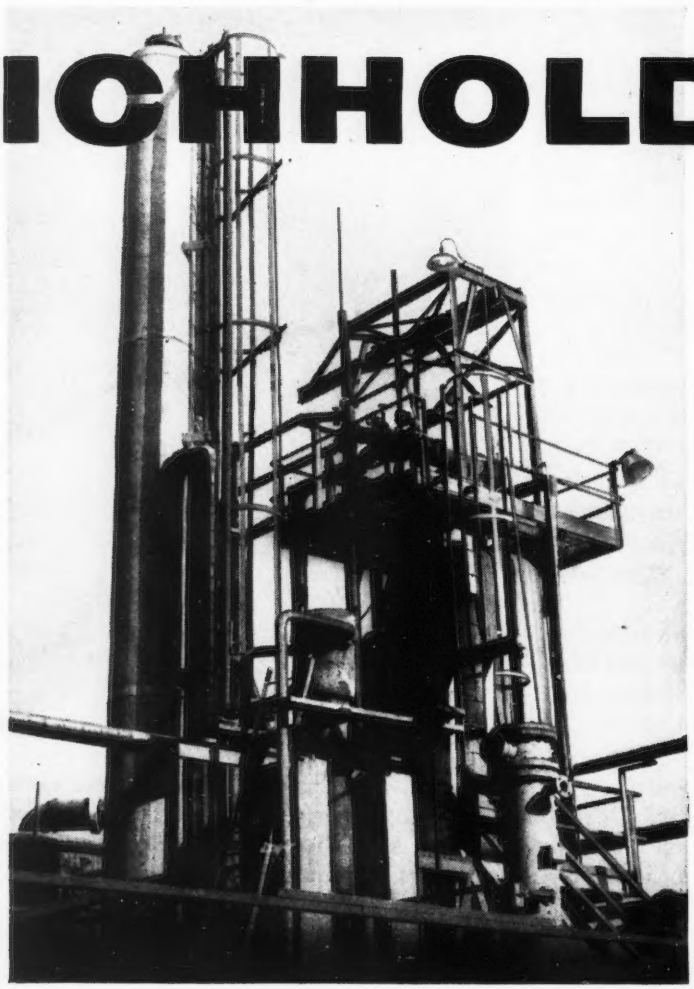

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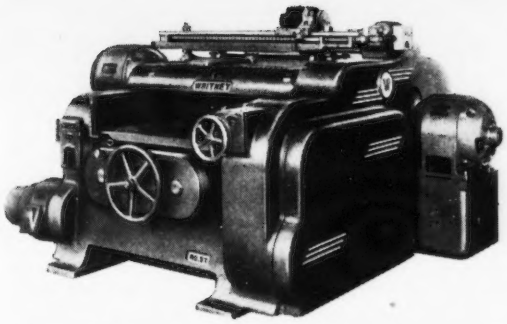

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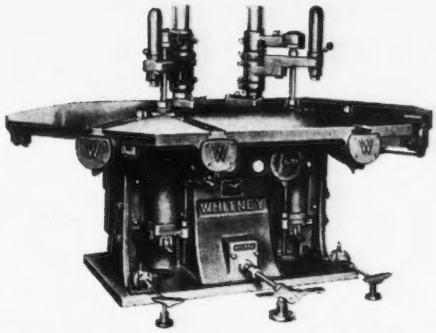

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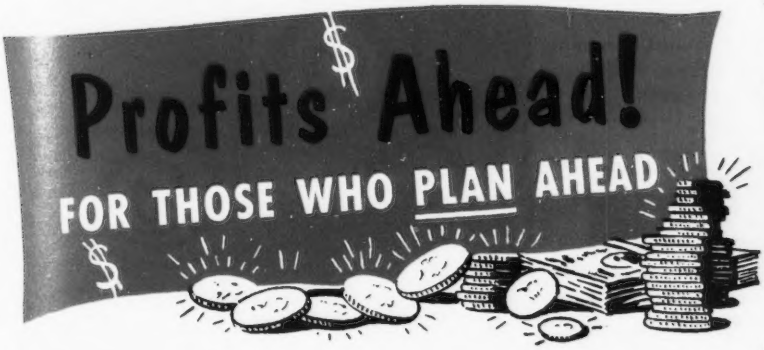

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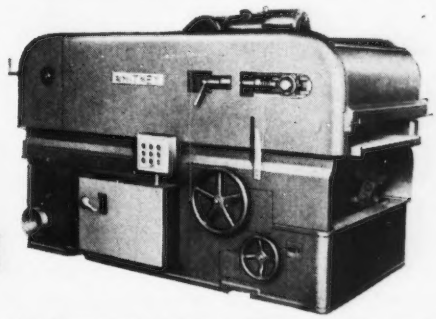

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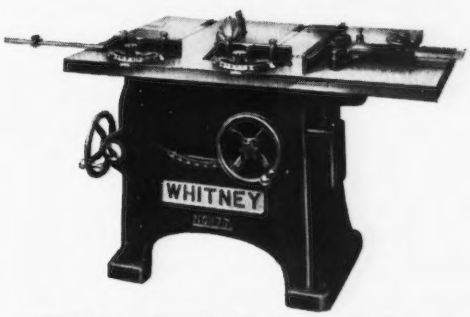

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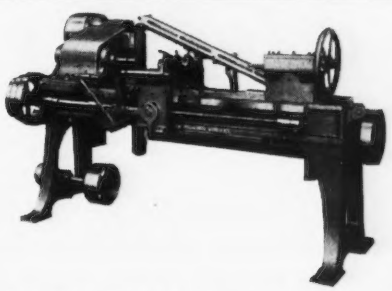

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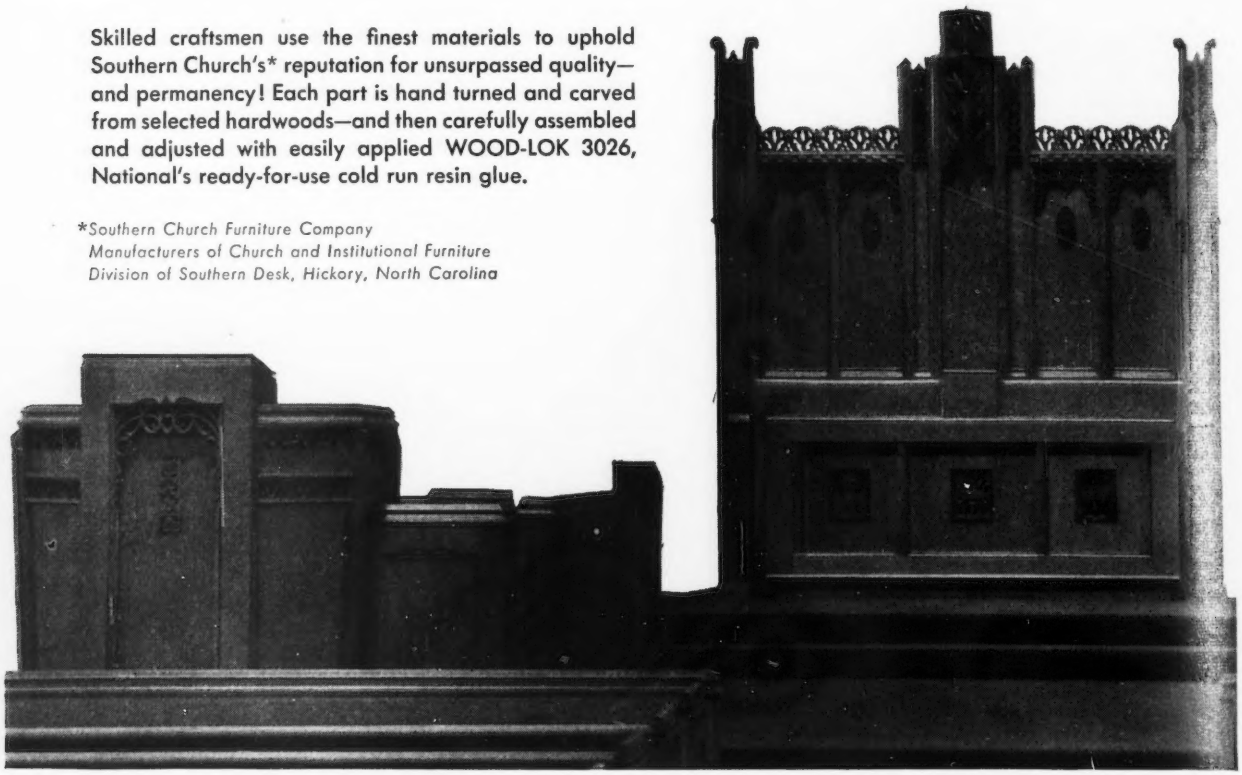

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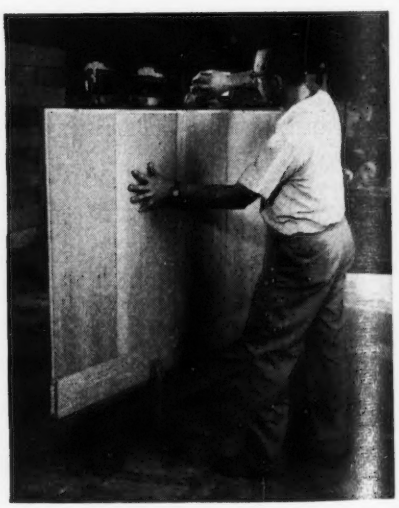

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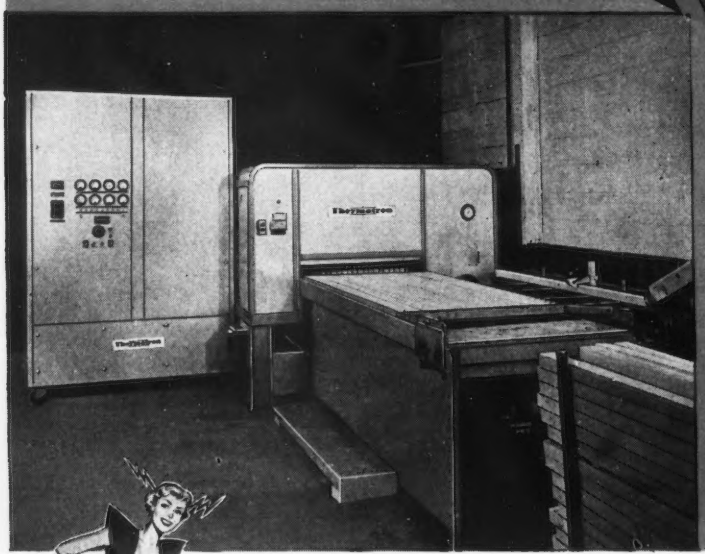

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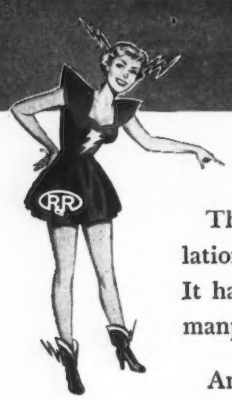

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November 2, 3, 1954: Two-day Upper Mississippi Valley Section Meeting at St. Paul, Minn.

November 4–5, 1954: Northeast Section Meeting at New York City.

December 1–2, 1954: Great Lakes Section.

December 7–10, 1954: Western Forestry Conference, San Francisco, Calif.

February 14–15, 1955 (tentative): Pacific Northwest Section Meeting at Seattle, Wash.

March 14–15, 1955: Eastern Canadian Section Annual Meeting at Chateau Laurier, Ottawa.

March 17–18, 1955: Executive Board Meeting at Madison, Wis.

June 20–23, 1955: 1955 NATIONAL MEETING at Seattle, Wash.

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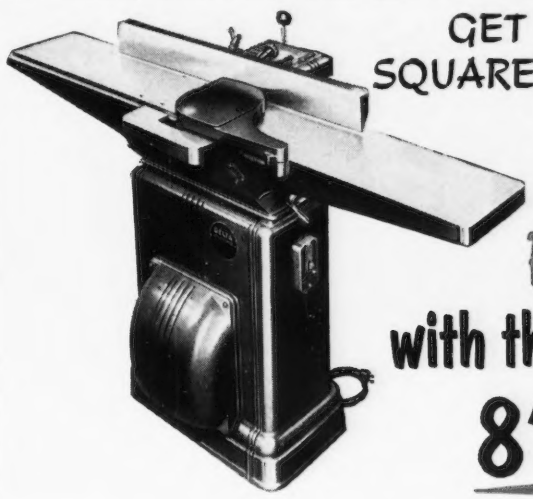

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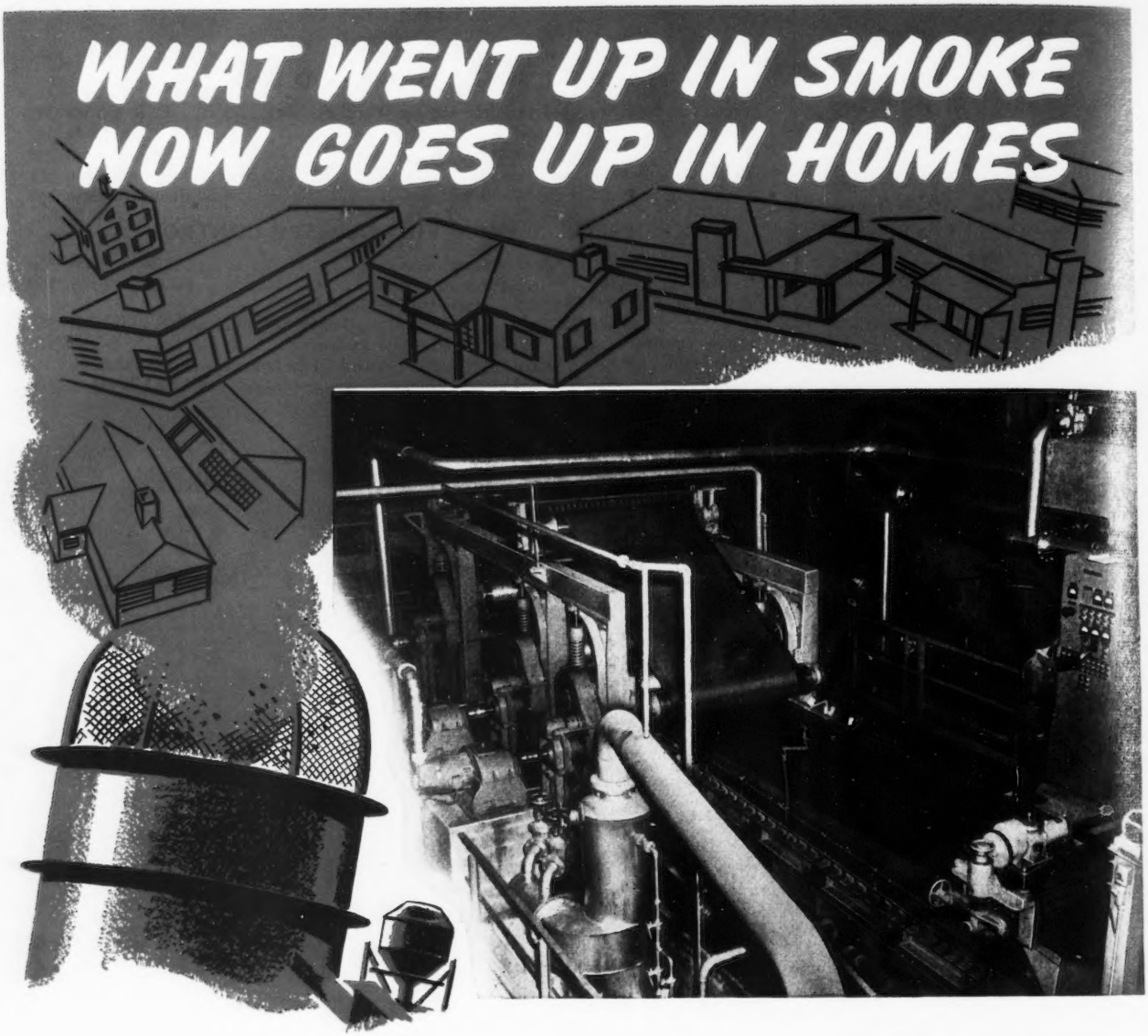

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Scott Lumber Co., Inc., Burney
Tarter, Webster & Johnson, Stockton
Winton Lumber Co., Martell
E. K. Wood Lumber Co., San Francisco

GEORGIA
Southern Wood Preserving Co., Atlanta

IDAHO
Potlatch Forests, Inc., Lewiston

ILLINOIS
The Dean Company, Chicago
General Electric, Illinois Cabinet Plant, Rockford
Greenlee Tool Co., Rockford
Edward Hines Lumber Co., Chicago
Illinois Interior Finish Co., Chicago
Johnson & Carlson, Chicago
Masonite Corp., Chicago
Mattison Machine Works, Rockford
Pressed Steel Car Co., Inc., Chicago
Sherwin-Williams Co., Chicago
Steger Furniture Mfg. Co., Steger

INDIANA
The Dunbar Furniture Mfg. Co., Berne
National Homes Corp., Lafayette
The Wood-Worker & Veneers and Plywood, Indianapolis

IOWA
Curtis Co. Inc., Clinton

LOUISIANA
A. J. Hodges Industries, Inc., Shreveport
Louisiana Long Leaf Lumber Co., Fisher

MARYLAND
National Store Fixture Co., Inc., Odenton
J. I. Wells, Salisbury

MASSACHUSETTS
Draper Corp., Hopedale
Heywood-Wakefield Co., Gardner
A. G. Spalding & Bros., Inc., Chicopee

MICHIGAN
Baker Furniture, Inc., Grand Rapids
The Dow Chemical Co., Midland
Everett Piano Co., South Haven
The Lloyd Manufacturing Co., Menominee

MINNESOTA
Mereen-Johnson Machine Co., Minneapolis
Rilco Laminated Products, Inc., St. Paul
Wabash Screen Door Co., Minneapolis

MISSOURI
Monsanto Chemical Co., St. Louis

NEVADA
Vaughn Millwork Co., Reno

NEW YORK
American Defibrator, Inc., New York
Borden Co., New York
Peter Cooper Corps., Gowanda
Oval Wood Dish Corp., Tupper Lake
Reichhold Chemicals, Inc., White Plains
United States Plywood Corp., New York

NORTH CAROLINA
The Champion Paper & Fiber Corp., Canton
Deluxe Saw & Tool Company, High Point

OHIO
The Baker Wood Preserving Co., Columbus
The Baldwin Co., Cincinnati
Coe Manufacturing Company, Painesville
The Kirk & Blum Mfg. Co., Cincinnati
Moraine Box Company, Dayton

OREGON
Cascades Plywood Corporation, Portland
Evans Products Co., Coos Bay
Forest Fiber Products Co., Forest Grove
J. Neils Lumber Co., Portland
Oregon Lumber Co., Baker
West Coast Lumberman's Assn., Portland

PENNSYLVANIA
Blaw-Knox Company, Pittsburgh
Firth Sterling Steel & Carbide Corp., Pittsburgh
Koppers Company, Inc., Pittsburgh
Perkins Glue Co., Lansdale
United States Steel Homes, Inc., Harrisburg
Wood Metals Industries, Inc., Kreamer, Snyder County

SOUTH CAROLINA
Lightsey Brothers, Miley

TENNESSEE
E. L. Bruce Co., Memphis
Chapman Chemical Company, Memphis
Memphis Hardwood Flooring Co., Memphis
Nickey Bros., Inc., Memphis

TEXAS
Wm. Cameron & Co., Inc., Waco
Kirby Lumber Corporation, Houston

VERMONT
Fyles & Rice Co., Inc., Bethel

WASHINGTON
American Marietta Co., Seattle
Deer Park Pine Industry, Inc., Deer Park
Douglas Fir Plywood Association, Tacoma
The Long-Bell Lumber Co., Longview
Simpson Logging Co., Shelton
Weyerhaeuser Timber Co., Tacoma

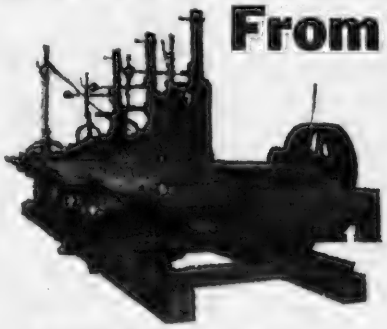
WISCONSIN
The Buckstaff Co., Oshkosh
Harnischfeger Corp., Port Washington
Marathon Corp., Rothschild
Mosinee Paper Mills Co., Mosinee
D. J. Murray Mfg. Co., Wausau
Paine Lumber Co., Oshkosh

ALASKA
Ketchikan Spruce Mills, Ketchikan

CANADA
British Columbia Lbr. Mfrs. Assn., Vancouver, B. C.
Canadian Forest Products Limited, New Westminster, B. C.
Canadian Siempelkamp Ltd., Hamilton, Ont.
Dominion Electrohome Industries, Ltd., Kitchener, Ont.
The Knight Mfg. & Lbr. Co. Ltd., Meaford, Ontario
MacMillan & Bloedel Limited, Nanaimo, B. C.
A. S. Nicholson & Son, Ltd., Burlington, Ont

ENTERPRISE

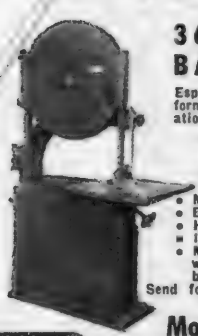
From FOREST



to FINISHED PRODUCT

MODELS 21 and 34
SAW MILLS

Built to withstand rugged service with continued accuracy, fast cutting and economical operation. Enterprise has been building machinery for over 75 years and our engineers have continued to incorporate all the latest advancements and improved designs in our standard sawmills. Special mills built to your individual requirements, related sawmill machinery and complete layout plans are available. Write for Bulletin 201.

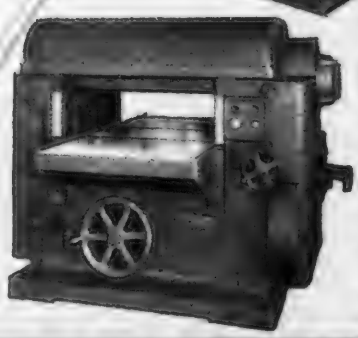


36 in.
BAND SAWS

Especially designed to perform multiple sawing operations under heavy production schedules, with speed, accuracy and low operating costs. Principal features include:

- Massive construction
- Ball bearing guides
- Handwheel tilt table
- 16 or 23 in. under guide
- Models for cutting wood—metal—plastics burlap—paper—rubber

Send for Bulletin 205—NOW



Model P-24
PLANER

A heavy duty, precision built single surfacer designed to produce a fine finish on a variety of planing jobs. Costly extra operations can be eliminated by obtaining a quality finish cut first on a Crescent Planer.

Join the many users, in pattern shops, manual training schools, furniture factories, and other industrial plants who have discovered that fast high speed planing with Crescent means low cost end products. For complete details of Models P-18 and P-24 Planers, write for free Bulletin 204.

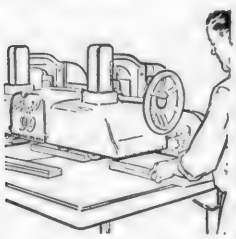
THE ENTERPRISE COMPANY
COLUMBIANA, OHIO

Worn-out machines
should be put out to
pasture too...

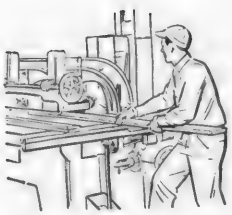
Modernize with DIEHL, for volume production . . . for bigger profits!

There is no getting around it . . . a machine built many years ago was fine for the job it had to do . . . *many years ago!* But in today's competitive market . . . where costs must be counted in fractions of cents . . . means that an *out-of-date, out-of-pace obsolete* machine must be *retired.*

Modern Diehl machinery designed for precision mass-production can help solve that *high unit cost* . . . help you keep in a healthy, competitive position by trimming production costs to a very minimum. With modern machinery you can reduce labor costs . . . rejects are cut down, your *downtime worries* are lessened, and the quality of your product is improved. *Delay* in replacing those old machines means *lost profits* . . . a definite expense.



Typical of *modern* Diehl machinery is the #99 Multi-Rip Saw, offering the woodworking industry *gang*-rip *mass production* with *single*-rip precision. Entirely *new unitized design,* with arbor, arbor motor and throat plate mounted *on the frame.* Easy operation, reduced set-up time, consistent accuracy . . . are a few of the advantages of the *rigid,* vibration-free #99. Eight powered feed rolls give smooth, positive feed of stock . . . eight feed speeds available (50-180 fpm) . . . and operator safety through double kick-back guards, are important features . . . designed for performance.



Another *modern* Diehl machine from the *complete Diehl line of modern woodworking machinery* is the #750 Straight Line Glue Joint Rip Saw. Unsurpassed for high-speed, tough sawing, for precision accuracy in cutting straight or hollow glue joints. Standard speeds are 58-90-120-180 fpm; special speeds up to 250 fpm. Handles stock from 1/8" to 4 1/4" thick . . . any length from 6" up. Massive, sturdy construction for long life and service. These are but *two modern Diehl machines* . . . if you are working with wood you need to know them *all. Each is outstanding in its job!*

A modern Diehl machine is an investment in *profits* . . . now and for the future. Let your Diehl Representative *prove* to you the burden of an obsolete machine; and how a modern Diehl machine can produce more for you at less expense.

Write today for complete line folder.

Standard of Comparison in the Woodworking Industry

THE G. M.

Diehl

MACHINE WORKS, INC.

WABASH, INDIANA, U. S. A.

DEPENDABLE ADHESIVES . . .

to help you make better wood products

MULTI-PURPOSE BONDS: UFORMITE 400 (high solids) and **UFORMITE 435** (low solids)—liquid urea-formaldehyde glues available in drums, tank wagons and tank cars for stable bulk or drum storage. **UFORMITE 505**—dust-free powdered (uncatalyzed) urea-formaldehyde glue. A variety of catalysts and formulations for trouble-free hot or cold bonding, as well as lumber core and high-frequency gluing.

COLD (OR HOT) BONDING: UFORMITE CB-553—dust-free powdered urea-formaldehyde glue (precatalyzed) for hot or cold bonding and high-frequency gluing.

TAPELESS VENEER SPLICING: UFORMITE JS-508—a one-component powdered glue that takes the guesswork out of tapeless splicing. For use on conventional or high frequency splicers.

BOIL-PROOF BONDS FOR EXTERIOR USE: AMBERLITE PR-14—a stable, powdered phenol-formaldehyde resin glue for hot pressing and bag molding of plywood. Boil-proof bonds for marine and other exterior uses.

DURABLE BONDS AT ROOM TEMPERATURES: AMBERLITE PR-115—an unmodified resorcinol adhesive for room or moderate temperature bonding and high-frequency cure. For heavy laminates or constructions where exceptional durability is required.

BONDS FOR THIN VENEERS: TEGO resin film—phenolic hot press adhesive in dry film form. Boil-proof bonds. Especially effective with thin and fragile veneers.

CHEMICALS FOR INDUSTRY

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

Representatives in principal foreign countries

UFORMITE, TEGO, and AMBERLITE *are trademarks, Reg. U.S. Pat. Off. and in principal foreign countries.*

ROHM & HAAS COMPANY, Resinous Products Division
Washington Square, Philadelphia 5, Pa.

Gentlemen: Please send me performance and technical data on the following:

- ☐ UFORMITE 400, 435
- ☐ UFORMITE CB-553, 505
- ☐ UFORMITE JS-508
- ☐ TEGO dry resin film
- ☐ AMBERLITE PR-14
- ☐ AMBERLITE PR-115

Name. . . . . .

Firm Name. . . . . .

City. . . . . *Zone*. . . . . *State*. . . . . .

FPRS NEWS-DIGEST

FOREST PRODUCTS RESEARCH SOCIETY, P. O. BOX 2010, UNIVERSITY STATION, MADISON, WISCONSIN

Volume 4 | OCTOBER, 1954 | Number 10

BUSINESS OUTLOOK

PROSPEROUS YEAR PREDICTED—Members of the Natural Resources Committee, U. S. Chamber of Commerce, see the year ahead as one of increased prosperity in the fields of lumber, natural gas, light metals, iron and steel, copper, livestock, and pulp and paper. Reports from petroleum, coal, lead, and zinc industries are less optimistic. Lumber: Corydon Wagner, v.p., St. Paul and Tacoma Lumber Co., reports production for 1954 is approaching record figures as a result of new construction throughout the country. Wood Products: Hillman Lueddeman, v.p., Pope and Talbot, Inc., reports progress in use of sawmill leftovers for new products: sawdust soil conditioners, wax and cork from Douglas-fir bark, wood molasses, sugar, alcohol, fodder yeast, and turpentine. Pulp and Paper: E. C. Rettig, Potlatch Forests, Inc., sees 1954 as record year.

—What's Happening In Forestry"

BUSINESS AT HIGH LEVEL—Current business activity is greater than in the great postwar boom of 1946-48 . . . far above the '49 recession and only slightly under mid-1950 conditions preceding the Korean War boom which peaked in the middle of

(Continued on page 74-A)

✻ BLACK BROTHERS have built more resilient roll glue spreaders during the past fifteen years than all other manufacturers.

Unmatched in speed, economy, accuracy, cleanliness and quality production . . . the No. 22D Ball Bearing, Resilient Roll Spreader is by far the finest glue spreader available for resins, caseins, and other cold glues. Gluing rolls are deeply covered with the fine synthetic rubber, and are specially grooved to control the amount of glue deposited and to conform to irregularities in the stock. Water cooled doctor rolls are available for use with quick setting glues. Accurate, heavy duty ball bearings are sealed to keep lubricants in, and dirt and glue out. Doctor rolls are heavily *coated* with a highly polished, nonferrous surface to accurately control the glue spread. Investigate the 22D Spreader today . . . write for supplement to Bulletin 11-A.

"If It Is Gluing Equipment — We Have It"

BB THE BLACK BROTHERS CO., INC.
MENDOTA, ILLINOIS, U. S. A.

YOUR GUIDE TO *Better* ADHESIVES . . .

The Perkins Trade Mark is your guarantee of quality and reliability when you purchase glues. Since 1899, customer-confidence in Perkins has grown steadily—a deserved tribute to superior products backed by competent service and rigid ethical standards. When you use a Perkins Glue in your operations, you'll agree with other leading woodworkers—*that Perkins serves you best!*

GLUING PROBLEMS?

Dispose of them by calling upon the skilled assistance of the Perkins Technical Service Department. Specialists in gluing methods will study your particular operations and offer suggestions where pertinent. There is no cost or obligation involved in your use of this unbiased advice.

IT'S A PERKINS SERVICE!

RESIN — Hot Press and Cold Press • Liquid or Powder Type
CASEIN — A broad line to meet your specific requirement
VEGETABLE — As originated and perfected by Perkins Glue Co.
ANIMAL — Ready-to-use Liquid • Heat-then-use Gel

• • •

VENEER AND CORE REPAIR COMPOUNDS • VENEER SIZE
GLUE ROOM SPECIALTIES • MIXERS • SPREADERS • BRUSHES

RESIN CASEIN **PERKINS** VEGETABLE GLUES

ESTABLISHED 1899

LANSDALE, PA. KITCHENER, ONT.

FPRS Eighth National Annual Meeting

ATTENDANCE FIGURES for the Eighth National Annual Meeting of the Forest Products Research Society soared to a new high of 830 for the three-day meeting held in cooperation with the Woodworkers Industry Show at Grand Rapids, Michigan May 5, 6, and 7, 1954.

The meeting was conducted jointly in the Hotel Pantlind and the Civic Auditorium. Another record was broken when over 4,000 wood industry executives attended the industry show run by Hiller and Stuart Co. in the Civic Auditorium.

The FPRS Executive Board met on May 4 before the meeting officially opened and made a number of important decisions. Preliminary plans were made to proceed with the construction of a permanent executive office building in Madison, Wisconsin, possibly early in 1955. The Board also voted, upon the recommendation of local sections to hold FPRS' 1956 National Meeting in Asheville, North Carolina, under the chairmanship of Dr. E. S. Harrar, Duke University, Durham, N. C. The 1955 National Meeting will be held June 20–23, at the Olympic Hotel, Seattle, Washington, under the general chairmanship of newly-elected Northwest Regional Board Member John D. Ritchie, Director of Allied Products, Douglas Fir Plywood Association, Tacoma, Washington.

Registration got underway the evening of Tuesday, May 4, at $6 for members, $10 for non-members. The FPRS Host Hour, co-sponsored by FPRS nationally and the Great Lakes Section, welcomed registrants with refreshments and conversation.

The opening day of the eighth national meeting, Wednesday, had many surprises in store for FPRS attendees. Experts in such varying fields as education, marketing, plywood, and other technical aspects of wood manufacture met at 13 major committee meetings, some attracting up to fifty committee members and guests at their discussions. (For committee reports refer to contents). Then plant tours started, and were overscheduled before the first bus-load left the Hotel Pantlind. The demand for visits to the John Widdicomb Furniture Co., American Seating Co., Grand Rapids Varnish Corp., Mueller Furniture Co., and Stow–Davis Furniture Co., was so great that tours were re-scheduled the second day of the meeting. Features which attracted large numbers of visitors follow: John Widdicomb Co.—one of the largest producers of fine modern and contemporary furniture in the Grand Rapids area. The American Seating Co., with three-quarters of a million square feet of floor space and over 2,000 employees,—the largest producer of school seating in the U. S. Grand Rapids Varnish Corp.—produced 3,750,000 gallons of finishing materials last year of which 60% was for wood finishing. Mueller Furniture Co., one of the old companies in Grand Rapids,—produces fine upholstered furniture and also a limited line of occasional tables. Stow–Davis Furniture Co.—produces a full line of wooden office furniture from standard work to the custom field which is its pride.

The mammoth Woodworkers' Industry Show opened its doors at noon to the hundreds who were waiting to see America's largest exhibit of woodworking machinery, in operation, and many auxiliary services and supplies.

Part of the hard-working National Meeting Committee.

J. P. Weyerhaeuser, Jr., speaking at official FPRS luncheon.

A forecast of big news ahead for the wood industry during the FPRS meeting came with the introduction of J. P. Weyerhaeuser, Jr., president of Weyerhaeuser Timber Co., before the official FPRS Luncheon gathering of 500 persons. Weyerhaeuser announced the nearly completed study of the Stanford Research Institute, under a Weyerhaeuser grant, which will project probable demands for forest products through 1975. See page 181.

Awards Presented

Traditional certificates and cash awards for outstanding university research in the forest products industry were presented to winners in the college graduate and undergraduate divisions of the Woodland Wood Products Award at the FPRS Luncheon by J. F. Koellisch, editor and manager of Wood

(Continued on page 23-A)

"WOODWORKING PLANT IN ITSELF"

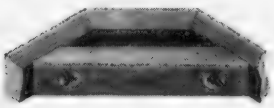
Greenlee Double-End Tenoner cuts costs fast

Many manufacturers have increased production, refined the quality of their products, and reduced unit costs substantially with a GREENLEE No. 545 Double-End Tenoner. This versatile machine performs many cost-cutting operations. It holds exact sizes over long production runs, thus eliminating costly "hand fitting" methods. Often referred to as "a woodworking plant in itself," it takes the place of several single-purpose machines and results in a highly streamlined, efficient production flow that produces finer products . . . in less time . . . at less cost . . . to meet today's market demands.

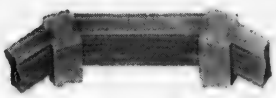
Write for Bulletin No. 545 **GREENLEE BROS. & CO.**
1760 Twenty-First Avenue, Rockford, Illinois

TYPICAL EXAMPLES OF WORK PRODUCED ON THE GREENLEE NO. 545 DOUBLE-END TENONER

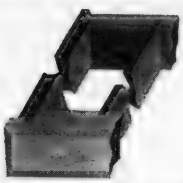
Dadoing, scoring, dovetailing, notching, relishing, sill-horning, and irregular shaping are among the 15 separate operations performed by this machine. Shown below are a few examples:



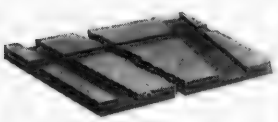
Mitering furniture rails



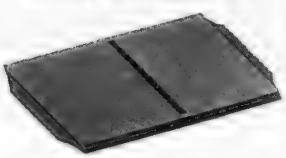
Dovetail jointing furniture rails



Cutting lock corner joints



Dadoing window frame stiles



Blind dadoing and relishing panels

Beveling and cutting clamp nail grooves

Sizing, tenoning, and coping door rails

GREENLEE

1954 Woodworkers Industry Show Sets Records

AN UNEXPECTEDLY LARGE number of sales by machinery manufacturers and suppliers substantiated the overwhelming success of the huge Woodworkers Industry Show held in the Civic Auditorium at Grand Rapids, Michigan, May 5–7, in cooperation with the Eighth National Meeting of the FPRS.

Approximately 4,000 wood industry executives attended the 3-day exhibition. Companies reported that they were surprised to find customers buying up machinery "on the spot". Many exhibitors shipped their machinery direct from display to customers' plants at the conclusion of the show. Sales were said to be made by a majority of firms exhibiting.

$1,000,000 of Machinery

There was nearly $1,000,000 worth of machinery represented; and over 50 machines in actual operation were tied-in to a specially installed Kirk and Blum dust collector system. According to A. Stuart, Grand Rapids and R. Hiller, Hartland, Wis., sponsors of the Woodworkers Industry Show, many executives were thus enabled to compare different makes of machines and services in action and made up their minds and placed orders.

Whether or not the persons attending actually bought equipment or supplies, they all came away from the show with numerous new ideas and plans for the immediate future. The growing awareness of the wood industry to the advantages of advanced mechanization and the use of modern high speed equipment and methods points the way to a more aggressive spirit toward competition being developed by the wood industry.

Newly designed automatic nailing machines, boring machines, moulders, planers, jointers, saws, finger joint machines, tongue and groove assemblies, sanding machines, rough mill equipment and other types of machinery were on display—many models for the first time—for the inspection of the visitors.

Besides machinery exhibits there were also all types of allied equipment and supplies. Glue presses, dry kilns, humidifying equipment, processing materials, adhesives, abrasives, wood treating chemicals, finishing materials, hardboard, chipboard, etc., were all represented.

Meet the Exhibitors

The complete list of exhibiting companies at the Woodworkers Industry Show included. Aget–Detroit Co., Louis Allis Co., American Cyanamid, Aries Fiberboard Corp., Armstrong Machine Works, Auto–Nailer Co., The Bahnson Co., Bell Machine Co., Berthelsen Engineering Works, Binks Mfg. Co., The Black Bros. Co., Boice-Crane Co., The Borden Co. Chem. Div., Buss Machine Works, Carter Products Co., Inc., C. K. L. Machine Co., Coe Mfg. Co., Curtis Machine Corp., DeBurgh Conveyors, Delmhorst Instrument Co., Dependable Machine Co., The DeVilbiss Co., The G. M. Diehl Machine Works, Henry Disston Sons, Inc., Alexander Dodds Co., James T. Donnolly Co., Ltd., Drake Corp., Econaway Mfg. Co., Ekstrom, Carlson & Co., Electronic Heating Corp., The Enterprise Co., J. A. Fay & Egan Co., Federal Electric Products, Fibresin Plastics, Fjellman & Winther Engineering, Foley Mfg. Co., John P. Fox Co., Inc., Greenlee Bros. & Co., Earle Hart Woodworking Mach. Co., Hawker Mfg. Co., Howell Electric Motors, Industrial Electronics, Irvington Machine Works, Kennametal, Inc., Kirk & Blum Mfg. Co., Leitelt Iron Works, Lemmon & Snoap, Mann–Russell Electronics, Marcoloy, Inc., Masonite Corp., Mattison Machine Works, McDonough Mfg. Co., Mereen–Johnson Machine Co., Moak Machine & Tool Co., Moisture Register Co., Monical Machinery Co., Monsanto Chemical Co., Moore Dry Kiln Co., J. M. Nash Co., National Adhesives, National Casein Co., Nelsonite Chem. Products, Newman Machine Co., Inc., Noble Machinery Co., North American Products Corp., Oliver Machinery Co., Onsrud Machine Works, Perkins Glue Co., Ply–Curves, Inc., C. O. Porter Machinery Co., Porter Stuart Co., Powers & Wire Products, Price & Rutzebeck, Protection Products Mfg. Co., Radial Cutter Mfg. Co., Redco Tool Co., Rees Blow Pipe Mfg. Co., Reeve Electronics, Inc., Rockwell Mfg. Co., B. M. Root Co., Senco Products, Inc., Sheboygan Machine Co., Simonds Saw & Steel Co., Sinker–Davis Co., Solem Machine Co., Stalter Edge Tool Co., Standard Dry Kiln Co., The Tannewitz Works, Timber Engineering Co., Timesavers, Inc., The Union Tool Corp., United Shoe Machinery Corp., L. R. Wallace & Co., Walters Mfg. Co., Baxter D. Whitney & Sons, Wilco Machine Works, Williams Patent Crusher & Pulverizer Co., Wisconsin Knife Works, Wolverine Finishes Corp., Woodwelding, Inc., Wysong & Miles, Yates–American Machine Co.

Seven universities and colleges arranged for space utilizing 3x5 table top exhibits donated by the Management.

Machine beveled, "Penacolite"-bonded ship rib—complete and ready to frame a vessel.

Penacolite®-bonded white oak replaces solid stock in marine members

built by Unit Structures, Inc.

TRADITIONAL sawed, shaped and bolted assemblies of solid stock have been replaced by machine beveled "Penacolite"-bonded white oak marine members built by Unit Structures, Inc. of Peshtigo, Wisconsin. The result: a combination of maximum strength with minimum weight—possible only with lamination. In addition, framing time is reduced and production costs are lowered.

Tough bonding jobs like this call for dependable "Penacolite" Adhesives. They are easy to work with and set quickly. "Penacolite" bonds are permanent—strong as the wood itself—and waterproof in both salt and fresh water. To find out more about "Penacolite" Adhesives and how they might help you, write to us today.

KOPPERS®

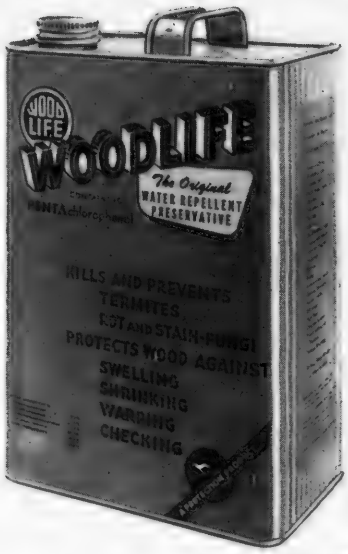
KOPPERS COMPANY, INC.

Chemical Division, Dept. FPRS-104, Koppers Bldg., Pittsburgh 19, Pennsylvania

PENACOLITE® RESORCINOL ADHESIVES

The original resorcinol, waterproof, room-temperature-setting adhesives

More than just a preservative



WOODLIFE

The Original WATER REPELLENT PRESERVATIVE

CONTAINING

PENTAchlorophenol

—the quality water repellent preservative.

Here's the finest protection wood can have . . . WOODLIFE—the original *water repellent* wood preservative. Effectively protects against water and moisture absorption, fungus decay, swelling, shrinking, warping, checking, grain raising, termites and insects. WOODLIFE actually exceeds the requirements of the Preservative Minimum Standards of the National Woodwork Manufacturers' Association and meets the specifications set-up by several departments of the Federal Government and Armed Forces. *Here's the finest protection wood can have!*

Send today for the informative folder, "WOOD PRESERVATION WITH WOODLIFE", which gives test data along with suggested specifications

Protection Products

MANUFACTURING COMPANY

Since 1921

Dept. C **Kalamazoo, Michigan**

Editorial

Pause for Reflection

THE EXHAUSTIVE and soundly-reasoned analysis made by the Stanford Research Institute covering America's demand for wood between 1929 and 1975 should give every person associated with the forest products industry cause for optimism coupled with reasonable caution.

Optimism is a characteristic at the very foundation of our American economic system, present in every business venture, and proven by the best living standards of people anywhere in the world. Optimistically the Stanford Report foresees the demand for forest products taking up our entire productive capacity, at rising prices for the next 20 years.

And while the Report forecasts favorable trends for most segments of our industry, it does so with the cautionary observation that for many, materials competitive to wood will continue to take an increasingly larger proportion of the consumer dollar. Recognition of this fact should challenge us to be alert to and incorporate technical advances into our thinking and our businesses if we are to successfully compete with encroaching materials.

To find out for yourself where your operation fits into this long-range picture we recommend that you carefully examine the next fifteen pages in which the editors have attempted to summarize the highlights of this study.[1]

The forest products industry generally and our Society in particular are indebted to the Weyerhaeuser Timber Company, through whose foresight and generosity these results have been made available. Weyerhaeuser provided the necessary funds for the Stanford study. When, late in 1953, it became apparent that the findings would be of great value to other companies in lumber, paper, plywood and wood products manufacture, they announced that the results would be shared by all. In so-doing Weyerhaeuser has again demonstrated the growing spirit of inter-cooperation toward a bigger and better forest products economy which today is welding every segment of our diverse industry.

The Forest Products Research Society was fortunate in having Mr. J. P. Weyerhaeuser, Jr., president of Weyerhaeuser Timber Company, address 500 members and guests at our Eighth National Meeting at Grand Rapids earlier this year. Referring to the study then underway, he said, "We are closer than many of us dared hope . . . to the day when all the forest products that our dynamic, growing economy demands can be met from current forest growth." Crediting true conservation, which he defined as the wise use of natural resources, with making it possible to meet the fast-growing demands for forest products without over-cutting existing forests, he continued that, "In whole log use, together with tree farming, lies the forest industry's practical answer to its critics who have cried 'Waste' in bygone days."

Competition, already keen, will become keener . . . "There is no blinking the fact that competing materials have made substantial inroads into the use of lumber in residential building, but lumber is still the material others have to beat; why else do others advertise that their product can be sawn like lumber, nailed like lumber, this and that like lumber? There is still no other building material with all the virtues and versatility of lumber." And, we might respectfully add, this same thinking applies to the many composite materials that are emerging from our forest residues.

Mr. Weyerhaeuser concluded on the note of optimism that "The Stanford Report is a most reassuring independent finding that forest products have a bright future."

[1] **Note:** The Weyerhaeuser Timber Company has generously offered to send a copy of the complete Summary Report on which the following article is based to any FPRS member or reader. Requests should be addressed: Public Relations Dept., Weyerhaeuser Timber Co., P. O. Box 1645, Tacoma 1, Washington.

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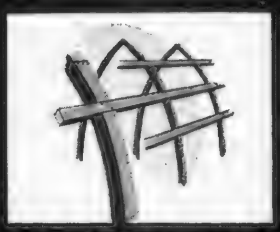

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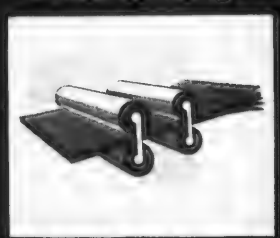

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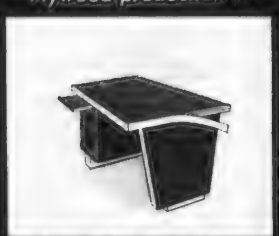

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SERVING INDUSTRY . . . WHICH SERVES MANKIND

America's Demand for Wood—1929-1975

A Report by Stanford Research Institute, Stanford, California[1, 2]

Condensation of a report sponsored and released by Weyerhaeuser Timber Company for the benefit of the entire forest products industries. Four principal objectives include: Estimation of consumption of major timber products at five year intervals through 1975; estimation of total amount of wood that will be required by producing mills in order to meet these requirements; explanation of variations in production and consumption of major timber products since 1929; and development of sound methods for estimating future levels of consumption of wood products and end-products.

Economic Growth of the United States, 1952–1975

UNDERLYING THE DEMAND for forest products is the size of the national economy and the ability of the economy as a whole to purchase these materials.

No attempt is made in this study to forecast future short-period ups and downs of business activity; the concern is with long-term growth, size, and levels of the economy.

Logical steps in analyzing the prospects for long-term growth of the United States economy were:

1. Population size, in total and by age groups.
2. Labor force, in total and by age groups.
3. Employment and the division of workers between private and public, and between military and civilian, employment.
4. Average hours of work per week (or per year).
5. Production per hour of work, in terms of Gross National Product (at 1952 prices).
6. Gross National Product, or the market value of all goods and services produced. This is calculated from the expected number of people working, their average hours of work, and their average production per working hour.

Based on the estimated Gross National Product, the following two series were estimated:

1. Disposable personal income payments to individuals (the portion of national product left to individuals, after taxes, for spending or saving).
2. Industrial production, a measure of activity in the manufacturing and mining segments of the economy.

Table 1 records these figures from 1929 through 1952, and the projections for 1960, 1965, 1970, and 1975, that will be used throughout this report as the economic framework for projections for individual industries and products. In Table 1, as throughout the report, all dollar amounts are in terms of 1952 price levels.

This economic framework and other findings of this study are based on the general assumptions that:

1. There will be no all-out war during the period covered by this study; however, a high level of military preparedness will continue.
2. There will be no radical advances in technology to increase productivity at a higher rate than in the past.
3. There will be a greater degree of stability in business cycles in future years than in the past twenty-five years. This stability will be accompanied by high, but not full, employment.

Table 1.—INDICATORS OF THE SIZE AND ACTIVITY OF THE UNITED STATES ECONOMY; ACTUAL 1929–52, PROJECTIONS 1960–75

Year	United States Population (1)	Total Labor Force (2)	Civilian Labor Force (3)	Civilian Employment (4)	Average Weekly Hours (5)	Gross Private Production per Man-Hour (6)	Gross National Product (7)	Disposable Income Payments to Individuals (8)	Index of Industrial Production		
									Durable (9)	Non-Durable (10)	Total (11)
1929	122	49.4	49.2	47.6	48.5	1.45	174	136	60	56	59
1930	123	50.1	49.8	45.5	47.0	1.42	158	126	45	51	49
1931	124	50.7	50.4	42.4	47.0	1.41	146	118	31	48	40
1932	125	51.2	51.0	38.9	45.3	1.36	125	101	19	42	31
1933	126	51.8	51.6	38.8	46.0	1.33	124	102	24	48	37
1934	126	52.5	52.2	40.9	44.2	1.44	138	111	30	49	40
1935	127	53.2	52.9	42.3	43.5	1.54	150	120	38	55	47
1936	128	53.7	53.4	44.4	44.2	1.62	170	138	49	61	56
1937	129	54.3	54.0	46.3	44.9	1.63	178	139	55	64	61
1938	130	55.0	54.6	44.2	43.1	1.68	170	130	35	57	48
1939	131	55.6	55.2	45.8	43.7	1.76	185	141	49	66	58
1940	132	56.0	55.6	47.5	43.4	1.87	202	149	63	69	67
1941	133	57.4	55.9	50.4	43.7	2.02	234	167	91	84	87
1942	135	60.2	56.4	53.8	45.1	2.04	262	183	126	93	106
1943	137	64.4	55.5	54.5	46.2	2.14	295	188	162	103	127
1944	138	65.9	54.6	54.0	45.9	2.31	318	202	159	99	125
1945	140	65.1	53.8	52.8	44.5	2.38	310	198	123	96	107
1946	141	60.8	57.5	55.2	42.8	2.26	280	202	86	95	90
1947	144	61.6	60.2	58.0	42.4	2.21	280	198	101	99	100
1948	147	62.7	61.4	59.4	42.3	2.25	290	203	104	102	104
1949	149	63.6	62.1	58.7	41.5	2.33	291	201	95	99	97
1950	152	64.6	63.1	60.0	41.8	2.46	316	219	116	111	112
1951	154	65.8	62.9	61.0	41.1	2.61	338	222	128	114	120
1952	157	67.4	63.0	61.3	41.7	2.64	348	224	136	114	124
1960	176	72.3	69.8	66.7	40.1	3.01	412	268	163	141	151
1965	187	77.6	75.1	72.2	39.1	3.24	465	298	189	159	172
1970	199	83.9	81.4	78.0	38.1	3.46	527	333	221	179	198
1975	212	90.7	88.2	84.4	37.1	3.65	586	367	251	198	222

Sources and Description of Data:

Col. (1): U. S. Bureau of Census; millions, continental U. S. plus armed forces overseas.
Col. (2) and (3): U. S. Bureau of Census; millions
Col. (4): U. S. Department of Commerce, *Survey of Current Business;* millions.
Col. (5) and (6): Derived from U. S. Dept. of Commerce and U. S. Dept. of Agricultural data; Gross Private Production per Man-Hour is at 1952 prices.
Col. (7) and (8): U. S. Dept. of Commerce; Billions of Dollars at 1952 prices.
Col. (9), (10) and (11): *Federal Reserve Bulletin,* December, 1953: Index, 1947–49 = 100.
All projections by Stanford Research Institute.

[1] A contributed article.

[2] Study directed by A. K. Beggs, Senior Economist; G. S. Gilligan, Associate Economist; H. C. Nielson, Research Economist.

Factors Affecting the Long-Range Demand, Supply, and Price of Forest Products

By 1975, three forest products—lumber, pulp, and plywood—are expected to take 90 per cent of total wood requirements, including all sizes and grades of material, and 95 per cent of sawlog-size wood.

Much of the demand for these forest products, or materials that compete with them, stems from three principal fields: construction, shipping containers, and manufactured products.

Because each of these forest products actively competes in each of these markets with numerous other materials, the future level of forest-products consumption in the United States will depend to a large extent on the prices of forest products in relation to the prices of competing materials. Estimates of future forest-products consumption without regard to price are meaningless. This is a study of probable market demand for forest products, not of what people might like to have, or of what someone thinks are the nation's needs.

Future forest-products market demand will depend on the level of activity in these major markets, on the available supply of forest products and the cost of making them, on the relationship between the price of each forest product and the prices of competing materials, and on changes in technology and consumer acceptance.

Long-Range Outlook for Construction

Table 2 shows expenditures (at 1952 prices) for major types of new construction in the United States from 1929 through 1952, with projections for 1960, 1965, 1970, and 1975. These projections are based on the past relatilonships between construction expenditures, population, and Gross National Product.

Within the industrial, commercial, and public utility group, a rise in public utility expenditures is expected to more than offset a substantial reduction in government expenditures for atomic energy facilities and other industrial plant.

The sharp increase in the classification "schools, hospitals, and institutions" is primarily for school buildings, reflecting a 56 per cent increase in school-age population between 1950 and 1975.

The outlook for residential construction activity can also be seen in terms of the expected number of housing starts. The projection of nonfarm housing starts is based on past relationships between new nonfarm housing starts and total population, annual changes in population, levels of real disposable income, and trend. Farm housing starts are projected on the basis that the number of farms is likely to decline by about 10,000 per year to 1975, but the number of dwelling units[3] per farm is expected to increase from the 1.2 of 1950 to 1.3 by 1975 as farms become larger and the population per farm (including hired hands) increases. Taking into account the replacement of farm dwelling units that has occurred in the past, the following projections of new housing starts result:

	Nonfarm	Farm	Total
1960	1,320,000	85,000	1,405,000
1965	1,470,000	85,000	1,555,000
1970	1,650,000	85,000	1,735,000
1975	1,860,000	85,000	1,945,000

Replacement of existing units is expected to account for a growing portion of the projected housing starts, ranging from around 500,000 housing units per year in the late 1950's to around 700,000 by 1975. Replacement does not imply the literal picture of one house being torn down and another erected in its place. Rather, a replaced housing unit may be torn down, stand vacant for an indefinite period, or be converted to some non-housing use; the unit that replaces it will normally be built elsewhere. It is possible that a high rate of replacement may be reflected in higher vacancy ratios than have been customary in the past.

[3] A separate residential unit with cooking facilities, whether in single houses or apartment-type structures.

Long-Range Outlook for Shipping Materials

Shipping containers, as distinguished from packing materials such as boxboard and glass, can be divided generally into two main groups:

1. The box and crate type, used primarily for shipping packaged goods and finished and semi-finished products, and
2. The bag- and drum-type, used primarily for materials shipped in liquid or bulk form.

To determine what change has occurred in demand for shipping containers, the various materials used in each group were converted to the number of equivalent containers of a standard size (1½ x 1 x 1 feet) producible annually. Allowing for the average weight of each type of material, as well as for such parts as flaps on fiberboard containers, the number of equivalent containers was calculated for each year from 1940 through 1952. Production of both container types fluctuates in the same proportion as changes in industrial activity, as measured by the Federal Reserve Board Index of Industrial Production. Total demand for shipping containers of both types is expected to increase by 85 per cent between 1952 and 1975. Competitive shifts of various materials within each shipping container type from 1940 through 1952, and the expected further shifts from 1952 to 1975, are shown in Table 3.

Table 2.—NEW CONSTRUCTION EXPENDITURES; ACTUAL, 1929–52 AND PROJECTIONS, 1960–75

(Billions of 1952 Dollars)

Year	Non-farm Residential	Industrial, Commercial and Public Utility	Schools, Hospitals and Institutions	Highways	Military and Naval	Other Non-Residential[1]	Total Non-Residential[1]	Total New Construction
1929	8.8	8.3	1.6	3.0	0.0	3.6	16.5	25.3
1930	5.2	6.9	1.7	3.6	0.1	3.8	16.1	21.3
1931	4.2	4.2	1.6	3.6	0.1	3.4	12.9	17.1
1932	2.1	2.4	0.8	3.0	0.1	2.5	8.8	10.9
1933	1.4	1.7	0.5	2.2	0.1	2.2	6.7	8.1
1934	1.8	1.8	0.8	2.5	0.1	2.4	7.6	9.4
1935	3.0	2.1	0.7	2.1	0.1	3.1	8.1	11.1
1936	4.7	2.7	1.2	3.5	0.1	4.3	11.8	16.5
1937	5.1	3.9	0.9	2.8	0.1	3.8	11.5	16.6
1938	5.1	2.8	1.2	3.3	0.1	4.0	11.4	16.5
1939	6.8	3.2	1.7	3.4	0.2	4.3	12.8	19.6
1940	7.6	4.1	0.7	3.1	1.0	3.9	12.8	20.4
1941	8.7	7.5	0.7	2.4	3.6	3.5	17.7	26.4
1942	4.7	9.2	0.6	1.3	9.8	2.1	23.0	27.7
1943	3.3	4.8	0.4	0.7	4.8	1.5	12.2	15.5
1944	1.9	4.1	0.4	0.7	1.5	1.3	8.0	9.9
1945	2.1	4.3	0.4	0.7	1.3	1.4	8.1	10.2
1946	6.8	6.7	0.6	1.4	0.3	3.0	12.0	18.8
1947	8.3	6.4	0.9	1.9	0.3	3.7	13.2	21.5
1948	10.0	6.7	1.4	2.2	0.2	4.7	15.2	25.2
1949	10.3	6.3	2.5	2.4	0.1	5.3	16.6	26.9
1950	14.5	6.6	2.5	2.7	0.2	6.0	18.0	32.5
1951	12.1	8.5	2.8	2.6	0.9	5.4	20.2	32.3
1952	11.8	9.0	2.7	2.9	1.4	4.5	20.5	32.3
1960	13.6	8.0	3.2	3.4	0.7	6.4	21.7	35.3
1965	15.0	8.7	4.1	3.7	0.6	7.7	24.8	39.8
1970	17.7	9.8	4.7	4.6	0.6	8.7	28.4	46.1
1975	19.5	10.8	5.1	5.0	0.5	10.8	32.2	51.7

[1] Includes farm residential.
Source: Actual—U. S. Department of Commerce; Projections by Stanford Research Institute.

Table 3.—TOTAL UNITED STATES CONSUMPTION OF SHIPPING CONTAINERS, BY TYPE
(Millions of Equivalent Containers 1 ½ x 1 x 1 Feet)
ACTUAL, 1940–52; PROJECTED, 1960–75

	Box and Crate Type					Bag and Drum Type								
Year	Corrugated	Solid Fibre	Wood	Plywood and Veneer	Total Box and Crate Type	Multi-Wall Sacks	Cotton Sacks	Burlap Bags	Steel Drums and Pails	Slack Cooperage	Tight Cooperage	Fibre Drums	Total Bag and Drum	Grand Total
1940	3,749	260	1,227	323	5,559	700	900	700	100	200	100	---	2,700	8,300
1941	5,288	323	1,571	332	7,515	1,000	1,000	700	200	200	100	---	3,100	10,600
1942	4,241	400	2,526	361	7,528	900	1,300	300	200	200	100	---	3,000	10,500
1943	4,784	469	3,382	352	8,987	1,100	1,400	400	300	100	100	---	3,400	12,400
1944	4,682	529	3,286	335	8,832	1,400	1,100	600	200	100	100	---	3,600	12,400
1945	4,811	485	3,000	309	8,606	1,500	1,000	900	200	100	100	---	3,800	12,400
1946	6,048	255	1,600	411	8,314	2,000	800	1,000	200	100	100	---	4,200	12,500
1947	6,295	257	1,440	308	8,299	2,400	800	900	200	100	100	---	4,500	12,800
1948	6,497	253	1,286	316	8,351	2,000	700	900	200	200	---	---	4,100	12,400
1949	6,435	215	1,086	333	8,068	1,800	700	800	200	100	---	---	3,700	11,800
1950	8,156	257	1,163	428	10,004	2,700	600	800	300	100	---	100	4,600	14,600
1951	7,934	317	1,349	503	10,103	3,000	600	600	300	100	100	100	4,700	14,800
1952	7,815	247	1,226	507	9,795	2,700	600	900	300	100	---	100	4,700	14,500
1960	10,037	246	1,365	652	12,300	3,800	600	1,000	300	100	---	200	6,000	18,300
1965	11,675	240	1,438	747	14,100	4,500	500	1,000	400	100	---	300	6,800	20,900
1970	13,524	225	1,497	853	16,100	5,400	500	1,000	400	100	---	400	7,800	23,900
1975	15,300	216	1,530	954	18,000	6,300	400	1,000	400	100	100	500	8,700	26,700

Sources: Actual derived from U. S. Department of Commerce data by Stanford Research Institute. Projections by Stanford Research Institute.
Note: Detail may not add to total, due to rounding.

Pallets afford another forest-products use. On the basis of the number of containers to be handled, the average pallet load, and a ten-year average life of pallets, annual pallet production is expected to go from about 20 million in 1952 to about 37 million by 1975.

Long-Range Outlook for Forest Products in Manufacturing

Although forest products are used in a wide variety of manufactured products, the furniture and fixtures industry is most important, representing almost half the consumption of lumber in all manufactures at the present time. Other large users are the railroad car and motor vehicles industries.

Furniture and fixtures shipments are expected to increase from $3,110 million in 1952 to $6,090 million by 1975. Household furniture expenditures are expected to rise from $2,351 million in 1952 to $4,730 million by 1975, and commercial, professional, and public building furniture and fixtures expenditures go from $759 million in 1952 to $1,360 million by 1975. These estimates are based on past relationships between furniture and fixtures expenditures and levels of personal disposable income.

Total railroad freight car output is expected to drop from 78,000 in 1952 to about 57,000 by 1975, based on the estimated inventory required in that year together with the estimated average age of cars of each type. Of the freight car types most important to the forest-products market, automobile cars, boxcars, and gondola cars will probably account for more than 90 per cent of total freight car production in 1975.

Output of trucks, truck-trailers, and busses is expected to increase about 70 per cent between 1952 and 1975. Truck production is expected to increase from 1.2 million in 1952 to 2.1 million by 1975. These estimates are based on correlation of motor-vehicle production with population and real disposable income payments.

In summary, this review of the outlook for the major forest-products markets indicates major expansion by 1975 in most markets. Questions remaining are the prospective supply and price of forest products and their impact on the competitive position of the various forest products.

Prospective Supplies and Relative Prices of Forest Products

Lumber: One of the fundamental problems of the national lumber industry is the cost of producing sawlogs. Through 1975 these costs will probably increase to such an extent that resulting lumber prices will continue to increase relative to those of competing materials.

Among the reasons why costs of producing sawlogs and lumber in the United States will probably continue to increase are these:

1. Costs of stumpage (stands of merchantable timber) are likely to keep increasing as the supply of available and readily accessible timber is reduced. Much will depend on the amounts cut from government-owned timber, especially in the West, where almost two-thirds of the commercial forest-land is government-owned. These amounts cut from government-owned timber have been rising in recent years, but they are still well below the allowable annual cuts consistent with sustained-yield management of the forests.
2. Logging costs are likely to rise as logging activity continues to shift to relatively remote areas or regions with rugged terrain, involving more difficult operations and higher log-transportation costs. The logging of lands with less volume per acre, and the declining size of trees being cut in all regions will also raise logging costs.
3. Manufacturing costs will probably be increased by the declining size of logs, rising labor costs (especially in the South), and an increased proportion of output from small, relatively high-cost mills as mill locations are adapted to scattered timber supplies.
4. Distribution costs, which represent about two-thirds of the cost of lumber to the consumer, will probably also increase. Transportation is a large part of this cost. The higher transportation cost to eastern markets for western lumber (which now accounts for more than 60 per cent of domestic softwood lumber production) as compared with southern lumber will tend to increase average lumber prices in coming years.

It is expected that annual U. S. lumber production will be moderately upward through 1975, increasing from the 1952 level of about 38.2 billion board feet to about 41 billion board feet by 1975.

In the production of this quantity of lumber, the relative position of the West is estimated to continue to rise as it has in recent years, accompanied by a relative decline in the position of the South, and little change in the East's relative position.

Considerable progress has been made for the past several years in placing the

nation's timberland on a sustained-yield basis. In the South, however, there is no apparent evidence that companies accounting for the major portion of total lumber production (as distinguished from pulp production) have generally made provision for future large-scale sawtimber supplies.

This outlook for the next twenty years is strongly influenced by the fact that two-thirds of the present sawtimber cut is in the West. If a projection were made to the year 2,000, the fact that the area east of the Rocky Mountains contains three-fourths of the forestland, as well as more than four-fifths of the population, would serve to temper the importance of the West over the longer period. It may be that the last quarter of the century will be marked by lumber production shifts opposite to those suggested for the next twenty years in this study, depending upon policies for timber restocking, forest management, and allocation of wood resources (as between lumber and pulp) followed in the South.

It would appear, therefore, that most of our future imports will be from Canada, largely from British Columbia. Since timber stands in that province can be cut less expensively than in the more northern provinces, and because of the nearness of this timber to the United States, it appears that increasing volumes of lumber will continue to flow into this country in future years.

Lumber demand would increase substantially if price relationships to competing materials stayed as they are. Only limited increases in domestic production and imports are in prospect without prohibitive increases in cost. Therefore, the price of lumber is expected to continue to rise more rapidly than the prices of competing materials. This increase in lumber price relative to prices of competing materials is expected, however, to be smaller during 1952–75 than it was in 1929–52, because the pressure of competing materials and technological developments will restrain increases in lumber prices.

Pulpwood, Pulp, Paper, and Paperboard: In pulpwood, pulp, paper, and paperboard production, supply factors indicate that the upward trend in production can be sustained during the next twenty years with costs maintaining their relation to competing materials about as they are now.

Historically, the expansion of the pulp industry has been due to its ability to develop additional sources of low-cost pulping materials through modification of its processes. Significant expansion of output during the *next* twenty years is expected in all the major grades of pulp except soda and sulphite pulp.

Utilization factors indicating expansion can occur without prices rising at a rate greater than prices of competing materials include:

1. The nature of the pulping process, which permits the economical use of small-size timber and forest residuals.
2. The development of more economical barkers and chippers, which can increase the supply of sawmill residuals for pulping.
3. The development of, and expected improvement in, semi-chemical pulping processes, which appear to be particularly well-suited to hardwood pulping.
4. Developments in sulphate pulping which have made it a versatile process capable of using practically all species of softwoods and hardwoods for all grades of pulp.
5. Adaptation of groundwood pulping to a wide range of species, including some hardwoods as well as southern pine and Douglas fir.

Insulating Board and Hardboard: It is expected that prices of insulating board and hardboard during the period covered by this study will tend to drop in relation to the prices of competing materials.

Increased interest in producing these products is evidenced by the entry of two western hardboard plants in 1953 and the expectation that six more will begin production in 1954. The recent development of these products has been largely based on utilization of mill residuals, defective timber, and species for which other uses did not exist.

It is entirely possible the heavy swing toward building board production will provide new capacity faster than the expected market growth. A major price drop may result. If this occurs, building board prices will then be very favorable in relation to those of competing materials.

Southern hardboard production must meet the competitive wood costs of the pulp industry. Under these conditions, there is little eagerness to enter the hardboard field in that region.

Plywood and Veneer: Supply and utilization prospects indicate the price of softwood plywood and veneer will probably rise in relation to the price of competing materials, but not as rapidly as hardwood products. It is expected the price rise will be relatively less than for lumber.

In the softwood plywood industry, the substitution of other materials for face veneer is likely to widen the log quality acceptable to the industry. Further improvements in patching techniques and expanded use of species other than Douglas fir will also help to broaden the supply base.

In the hardwood plywood and hardwood face veneer industries, present costs are at such a level that imports of comparable quality can be sold for less than domestic production, and considerable markets have been lost to imports during the last two years. No great change is expected in the price of utility grades of hardwood plywood compared with competing materials, but hardwood plywood output is expected to meet more competition from softwood plywood and hardboard.

Largely as a result of using low-grade veneers in shipping containers, both softwood and hardwood container veneer are expected to maintain present price relationships with competing materials.

To sum up this review of supply and price prospects for the major forest products, the following price shifts relative to competing material are expected:

1. Although lumber prices will probably rise more rapidly than the prices of competing materials, the relative increase is expected to be smaller in the 1952–75 period than it was between 1929 and 1952.
2. Pulp prices are expected to remain approximately the same in relation to prices of competing materials as formerly.
3. Hardwood and insulating board prices are expected to be slightly lower in the future in relation to prices of competing materials.
4. Plywood prices are expected to increase slightly in relation to price of competing materials, but not as much as lumber prices.

The Demand for Lumber

In 1953 about 73 per cent of total United States lumber consumption went into construction; about 15 per cent into shipping, including boxes and crating materials, dunnage, and pallets; and the remaining 12 per cent into manufacturing products. These proportions are expected to be about the same in 1975 as in 1953, despite some significant shifts within these broad groupings.

Lumber used in construction, for example, is likely to be centered increasingly in new residential building (including additions and alterations), with a smaller share going into non-residential construction, and about the same proportion as now into maintenance and repair of all types of construction.

Lumber Use in Residential Building

Lumber demand for new dwelling units[4] changes from year to year in

[4] Dwelling unit is defined in footnote on page 182.

response to changes in the number of dwelling units under construction, architecture, size and height of the dwelling structures, and competition from other materials. The following table shows the changes in these factors from 1920 through 1953, and further changes to 1960, 1965, 1970 and 1975 on which calculations of lumber demand for new residential building are based:

(INDEX NUMBERS, 1920 = 100)

Year	Number of Starts	Floor Space per Unit	Total Floor Space	Average Ceiling Height	Average Cubic Volume of Unit	Actual Lumber Consumption	
						Per Unit	Total
1920	100	100	100	100	100	100	100
1930	109	86	94	99	86	81	89
1940	185	82	152	96	79	74	136
1950	433	75	322	92	69	62	268
1953	342	76	260	90	68	56	190
1960	405	76	308	90	68	53	213
1965	448	76	340	89	67	51	228
1970	500	76	380	89	67	48	241
1975	561	76	426	89	67	46	257

The housing-start index consistent with data in the preceding section, including farm and non-farm starts.

Little change is foreseen in the distribution of dwelling-unit starts as between single-family, two-family, and multi-family structures. The continued industry movement to suburban areas and expectations of attractive financing for prospective home-owners should maintain the popularity of the single-family structure.

The size of dwelling units in the future will depend primarily on the money expected to be available for an average dwelling unit in relation to the cost per square foot. The average expenditure per non-farm dwelling unit, based on figures for projected housing expenditures and number of starts shown in the preceding section, is as follows, in terms of 1952 prices:

1952	$9,338
1960	9,318
1965	9,387
1970	9,757
1975	9,677

The future outlook is for construction materials costs, in terms of 1952 prices, to increase. No relative decline in construction labor costs is expected. A greater number of built-in appliances and more utility features such as bathrooms and electrical circuits will probably be used. Because of this, an average annual increase of 1½ cents per square foot (at 1952 prices) in residential construction costs appears reasonable. Furthermore, with larger roof overhangs and more additions such as patios and garden houses for outdoor living, the cost of construction will tend to increase without being reflected in the size of the average dwelling unit.

Based on these considerations, the cost per square foot of a 1,000—square—foot dwelling unit would increase from $9.28 in 1952 to $9.63 (at 1952 prices) by 1975; for a 900-square-foot unit, with a greater proportion of cost in such "fixed" items as heating, wiring, and plumbing, the corresponding figures are $9.71 in 1952 and $10.06 in 1975.

The net result is that the average dwelling unit size is expected to be about 1,000 square feet for each of the target years through 1975. These estimates are further buttressed by past experience in residential construction. The average size of dwelling units has been declining and so has the average number of persons per unit, Table 4.

Roughly half of the decline in lumber use between 1920 and 1935 was due to changes in the size and architecture of dwellings; this represented a market loss for competing materials too. Of the market remaining, the consumption of lumber in 1920 was about 63 per cent of the maximum possible. By 1950 this had dropped slightly to about 59 per cent of the maximum possible, but by 1953 it had fallen to about 52 per cent. Thus, between 1950 and 1953 lumber participation fell off more rapidly than it did in the previous thirty years. This loss was largely attributable to the growing popularity of slab-type construction, which cut into lumber's market for foundations, floor framing, sub-flooring, and finished flooring.

Table 5 shows the changes in lumber use per dwelling unit, by components of the house and in total, from 1920 through 1953, with projections to 1975.

The roof is now the most important component of the dwelling unit in terms of actual lumber consumption. Next is the roor, followed by exterior and interior walls. These four components account for more than 70 per cent of the lumber consumed per dwelling unit.

Table 6 shows the division of past and probable lumber use per dwelling unit by type of lumber.

Framing lumber had about 62 per cent of its maximum possible market in 1920, as compared with about 53 per cent in 1953. By 1975, framing lumber is expected to have about 48 per cent of its possible maximum market. (This includes a minor quantity of finished boards used for interior walls and ceilings.)

Sheathing lumber accounted for about 80 per cent of the sheathing market in 1920, but only about 58 per cent in

Table 4.—EFFECT OF ARCHITECTURAL CHANGES AND COMPETITION ON LUMBER CONSUMPTION IN NEW RESIDENTIAL CONSTRUCTION

Per Dwelling Unit and Total, 1920–1975—Total Lumber

Year	Per Dwelling Unit (BF) Loss Due to					Total, All Dwelling Units (MMBF)		
	Maximum Possible	Architecture and Design[1]	Competing Materials	Actual Lumber Use	% of Maximum	Maximum Possible	Competing Materials	Actual Lumber Use
1920	30,184	------	11,282	18,902	63%	10,476	3,906	6,570
1930	25,165	5,019	9,778	15,387	61%	9,520	3,705	5,815
1940	22,409	7,775	8,511	13,898	62%	14,430	5,476	8,954
1950	20,011	10,173	8,294	11,717	59%	30,060	12,455	17,605
1953	20,356	9,828	9,836	10,520	52%	24,159	11,677	12,482
1960	20,037	10,147	10,085	9,952	50%	28,179	14,184	13,995
1965	19,946	10,238	10,334	9,612	48%	31,053	16,092	14,961
1970	20,017	10,167	10,894	9,123	46%	34,750	18,920	15,830
1975	19,773	10,411	11,067	8,706	44%	38,484	21,567	16,917

[1]Based on difference between maximum possible market per dwelling unit in 1920 and in year shown.

Table 5.—TOTAL CONSUMPTION OF LUMBER PER DWELLING UNIT BY COMPONENTS OF HOUSE AND IN TOTAL, 1920–1975

(Board Feet)

Year	Foundations	Floors	Ceilings	Roofs	Exterior Walls	Interior Walls	Millwork	Accessory Buildings and Miscellaneous	Total
1920	1,720	4,270	975	2,790	2,520	2,930	2,621	1,076	18,902
1930	1,369	3,670	832	2,260	2,370	2,289	1,930	667	15,387
1940	1,280	3,320	798	2,540	2,100	1,712	1,398	750	13,898
1950	1,086	2,540	759	2,600	1,748	1,518	1,050	416	11,717
1953	895	1,970	793	2,400	1,598	1,529	930	405	10,520
1960	828	1,799	785	2,339	1,423	1,513	860	405	9,952
1965	762	1,590	776	2,310	1,420	1,534	815	405	9,612
1970	682	1,410	776	2,230	1,340	1,520	760	405	9,123
1975	610	1,240	769	2,200	1,262	1,505	715	405	8,706

Source: Stanford Research Institute.

1953. It is estimated that by 1975 sheathing lumber will have only about 43 per cent of the potential sheathing market.

Although lumber siding increased its part in the exterior-facing materials market from about 21 per cent to about 28 per cent between 1920 and 1953, total consumption of siding per dwelling unit has slumped from about 400 board feet to about 325 board feet. It is estimated that about 250 board feet of siding will be used per dwelling unit in 1975, representing about 23 per cent of total siding potential.

Hardwood lumber consumption in 1953 accounted for only about 64 per cent of the maximum possible hardwood lumber market (flooring and millwork), as compared with about 98 per cent in 1920. It is estimated that by 1975 hardwood lumber will have 39 per cent of its total market, due largely to the loss of flooring markets, but also to stiff competition from other materials in millwork markets.

Some of the loss of lumber markets in residential building is to other forest products such as plywood, hardboard, and insulating board. As shown in table 7, these products accounted in 1953 for a little less than 12 per cent of lumber's total loss of markets to competing materials. All three are expected to show substantial growth in residential building uses by 1975, and they are expected to account by that time for about 15 per cent of the total loss of lumber markets to competing materials.

Additions and Alterations

Consumption in additions and alterations in 1953 represented about 4 per cent of total lumber consumption in construction of all types.

It is estimated that about one board foot of lumber was consumed per dollar of addition and alteration expenditures in 1953; it is expected that this lumber-use factor will decline by 1975 to about 0.85 board feet per dollar. Competition from plywood, hardboard and insulating board will tend to reduce the boards consumer per dollar of expenditure, but the quantity of dimension lumber consumed per dollar will probably remain at present levels.

The expected decline in the lumber-use factor, however, is offset by probable increases in total expenditures for this type of construction, from $1.1 billion in 1953 to $1.25 billion (at 1952 prices) by 1975. As a result, lumber used in additions and alterations is expected to remain close to present levels (about 1.1 billion board feet annually) throughout the period to 1975.

Lumber Use in Nonresidential Construction

A special survey made in 1953 by Stanford Research Institute of 1,000 large non-residential contractors shows that lumber consumption in non-residential construction of all types can be allocated by end-use as follows:

Lumber Use	*Percentage of Total*
Concrete forms	58%
Framing and trim	20
Scaffolding	10
Bracing, shoring, decking, etc.	9
Temporary buildings, skids and other uses	3
Total	100%

Lumber is used in preference to plywood, hardboard, or steel in concrete forms because it is more economical where large, smooth surfaces are not required. Lumber can be re-used for concrete forms and later utilized for bracing, shoring, or for temporary buildings and fencing. Because of the many possible re-uses, it appears likely that lumber will retain a portion of the concrete form market in future years. Plywood and hardboard provide the greatest competition in concrete forms where smooth surfaces are desired.

The closest competitors of lumber for framing, scaffolding, bracing, shoring, and decking are steel or concrete and steel. The principal advantage of lumber is its lower cost and its workability, resulting in lower total installed cost or total use cost. In many cases, however, steel or steel together with concrete are used because they offer additional strength.

Lumber-use factors by type of nonresidential construction, based on the special survey made in 1953, are as follows, with projections for 1975:

Type of Construction	Lumber Consumed per Dollar of Expenditure (Board Feet)	
	1953	1975
Industrial Plant	.384	.20
Industrial and commerical building	.448	
Public utilities	.300	
Institutional	.320	.24
Educational	.295	
Hospital and other institutional	.400	
Farm service buildings	1.200	.80
Highways	.277	.15
Public works	.281	.15
Sewer and water	.296	
Conservation and development	.266	
Military and naval	.257	.14
All other	.386	.21

An over-all decline of about 45 per cent in the board feet of lumber consumed per dollar of nonresidential construction is expected in the period between 1953 and 1975. These declines in lumber-use factors range from about 25 per cent in institutional building to 50 per cent in highway construction.

By combining these lumber-use factors with estimated expenditures for each type of nonresidential construction (as shown in Table 2 of this report), estimates were made of lumber consumption for each of the target years. Estimates for 1953 and 1975 are shown below.

Table 6.—TOTAL CONSUMPTION OF LUMBER PER DWELLING UNIT BY TYPE OF LUMBER, 1920–75

(Board Feet)

Year	Framing Lumber	Wood Sheathing	Wood Siding	Hardwood	Total
1920	13,100	4,250	400	1,150	18,900
1930	10,450	3,500	450	1,000	15,400
1940	9,150	3,350	450	950	13,900
1950	7,800	2,850	350	700	11,700
1953	7,400	2,200	325	575	10,500
1960	7,200	2,000	250	500	9,950
1965	7,000	1,850	300	450	9,600
1970	6,750	1,700	275	400	9,125
1975	6,500	1,600	250	350	8,700

Source: Stanford Research Institute.

Table 7.—LOSS OF LUMBER MARKET TO OTHER WOOD PRODUCTS IN NEW RESIDENTIAL CONSTRUCTION

(Million Board Feet)

Year	Total Loss to Competition	Board Foot Equivalent Loss to:			Total Wood Products	Percent of Total Loss
		Plywood	Hardboard	Insulating Board		
1920	3,906	34.3	-----	124.1	158.4	4.1
1930	3,705	46.9	-----	104.5	151.4	4.9
1940	5,476	143.7	-----	142.4	286.1	5.2
1950	12,455	458.4	28.5	384.9	871.8	7.0
1953	11,677	1,013.8	109.2	256.2	1,379.2	11.8
1960	14,184	1,271.0	263.5	411.2	1,945.7	13.7
1965	16,092	1,405.3	421.3	467.3	2,293.9	14.3
1970	18,920	1,647.3	570.9	543.2	2,761.5	14.6
1975	21,567	1,786.0	762.1	679.0	3,227.1	15.0

Source: Stanford Research Institute.

Type of Construction	Estimated Lumber Consumption in Non-Residential Construction (Millions of Board Feet) 1953	1975
Industrial, commercial and public utility	3,916	2,160
Institutional	929	1,224
Farm service buildings	977	400
Highways	871	750
Military and naval	350	70
Public works	450	255
All other	697	216
Total	8,190	5,075

Lumber Use in Maintenance and Repair

In 1953, lumber consumption in maintenance and repair of both residential and nonresidential structures represented about 23 per cent of lumber consumed in construction of all types, and 16 per cent of lumber consumption in all uses.

The use of lumber per dollar of expenditure for maintenance and repair is expected to decline from about 0.68 board feet in 1953 to about 0.60 board feet by 1975, largely as a result of increased competition from insulating board, hardboard, and plywood, which are more easily installed by the amateur. As in the additions and alterations market, little competition is foreseen here for dimension lumber.

The decline in the lumber-use factor is offset, however, by the expected increase in maintenance and repair expenditures. With a larger number of structures in the inventory by 1975, coupled with the expected continuation of the "do-it-yourself" trend, together with increased leisure time, increased maintenance and repair expenditures appear likely.

Lumber consumption for maintenance and repair, therefore, is expected to increase from 6.8 billion board feet in 1953 to about 7.2 billion board feet by 1975.

Railroad Ties

Lumber used for railroad ties now represents about 2 per cent of total lumber consumption in all uses. Of all railroad ties, lumber (sawn ties) is used exclusively for switch and bridge ties and for more than half of the cross ties on main and branch lines and in sidings. The remaining cross ties are hewn wood ties, not classified as lumber. On the basis of 40 board feet per cross tie and with 52.5 per cent sawn, total lumber consumption in cross ties for all roads by 1975 is estimated to equal 610 million board feet.

Total Lumber Use in Construction

Table 8 summarizes the estimated distribution of lumber consumption in construction, including maintenance and repair, alterations and additions, sawn railroad ties, and mine timbers, for 1930, 1940, 1950, and 1953, with projections at five-year intervals to 1975. The major shift indicated for construction uses of lumber is the increased proportion expected to be used in residential building and the reduced usage in nonresidential construction. Despite the expected increase of more than 4 billion board feet in annual residential building use by 1975, total lumber used in construction is expected to increase by only 1.7 billion board feet.

Table 8.—ESTIMATED DISTRIBUTION OF LUMBER CONSUMPTION BY USE IN CONSTRUCTION, INCLUDING MAINTENANCE AND ALTERATION, 1930–75

(Millions of Board Feet)

Year	Residential	%	Nonresidential	%	Maintenance and Repair	%	Sawn Railroad Ties and Mine Timbers	%	Total	%
1930	7,000	34.4	6,940	34.1	4,000	19.7	2,406	11.8	20,346	100
1940	9,900	35.5	12,092	43.3	4,200	15.1	1,707	6.1	27,899	100
1950	18,900	58.8	5,574	17.3	6,600	20.5	1,065	3.3	32,139	100
1953	13,900	46.4	8,190	27.4	6,800	22.7	1,039	3.5	29,929	100
1960	15,300	52.5	5,620	19.3	7,150	24.6	1,052	3.6	29,122	100
1965	16,150	55.0	5,080	17.2	7,050	24.0	1,058	3.8	29,338	100
1970	17,200	56.5	5,150	16.9	7,050	23.1	1,059	3.5	30,459	100
1975	18,300	57.9	5,075	16.0	7,200	22.8	1,053	3.3	31,628	100

Source: Stanford Research Institute.

Use of Lumber in Shipping Materials

Of lumber used for shipping in 1952, about 69 per cent was for boxes and other types of wood packing, about 22 per cent for dunnage, and about 9 per cent for pallets.

Lumber consumption in boxes, crates, reels, and other shipping containers has been declining for the past several decades, largely due to increased competition from paperboard containers. (Table 3 of this report shows the division of the total container market since 1940, with projections.) In general, the advantages of strength, appearance, and re-use possibilities associated with wooden boxes are outweighed by their cost, weight, related increase in packaging time, and problems connected with opening, handling, and disposition. So it is expected that wood will continue to decline in market participation.

Increased total demand for shipping containers will, however, offset the decline in percentage of the market enjoyed by the wooden container industry. On this basis, lumber consumption in wooden boxes and crates is expected to climb from about 4.3 billion board feet at present to about 5.3 billion board feet by 1975.

Lumber required for pallets is expected to increase to about 1,230 million board feet by 1975, as compared with 660 million board feet in 1952.

The demand for dunnage is expected to fail to keep pace with increases in shipping activity in future years, because materials-handling methods will be improved. A consumption estimate of about 750 million board feet of lumber for dunnage by 1975 reflects this relative downward trend.

Table 9 summarizes past and expected consumption of lumber in shipping, by type and in total.

Table 9.—UNITED STATES CONSUMPTION OF LUMBER IN SHIPPING, BY TYPE, 1940–1975

(Millions of Board Feet)

Year	Wood Used for Boxes, Crating	Wood Used for Dunnage	Wood Used for Pallets	Total
1940	4,300	1,000	200	5,500
1941	5,500	1,000	300	6,800
1942	8,840	1,200	400	10,440
1943	11,838	1,962	400	14,200
1944	11,500	2,614	386	14,500
1945	10,500	1,200	300	12,000
1946	5,600	1,000	250	6,850
1947	5,040	1,000	225	6,265
1948	4,500	1,000	220	5,720
1949	3,800	1,000	200	5,000
1950	4,070	1,200	765	6,035
1951	4,720	1,400	830	6,950
1952	4,290	1,500	660	6,450
1953	4,350	1,400	600	6,350
1960	4,780	1,000	800	6,580
1965	5,030	900	900	6,830
1970	5,240	800	1,130	7,170
1975	5,350	750	1,230	7,330

Source:
Actual—Derived from U. S. Department of Agriculture data.
Estimate—Stanford Research Institute.

Use of Lumber in Manufactured Products

Lumber demand for manufactured products amounts to about 5 billion board feet annually. Of this, the furniture and fixtures industry is most important, accounting for almost half. Lumber for railroad cars represents about 4 per cent of lumber used in manufacturing, while lumber in motor vehicles account for about 2 per cent of the total. The bulk of the remaining 47 per cent is used in housetrailers, venetian blinds, agricultural implements, handles, ladders, tanks, pencils, patterns, caskets, boots, musical instruments, athletic goods, and toys. Lumber demand for these miscellaneous items is considered as a group because of the relative unimportance of any one in the total demand picture.

Table 10 shows the dollar value of furniture and fixtures output at 1952 prices, the board feet of lumber consumed per dollar of output, and the resulting lumber used in furniture and

Table 10.—UNITED STATES LUMBER CONSUMPTION IN FURNITURE AND FIXTURES, 1929–1975

Year	Total Output (Million of 1952 Dollars)	Board Feet of Lumber per Dollar	Lumber Consumption (Million Board Feet)
1929	1,710	1.08	1,845
1930	831	1.05	873
1931	993	1.02	1,013
1932	----	----	----
1933	702	0.99	692
1934	1,069	0.95	1,016
1935	870	0.91	792
1936	1,545	0.87	1,344
1937	1,376	0.83	1,142
1938	1,435	0.79	1,134
1939	1,424	0.75	1,068
1940	1,780	0.71	1,260
1941	2,125	0.71	1,510
1942	2,470	0.71	1,750
1943	2,690	0.70	1,880
1944	2,990	0.70	2,090
1945	2,990	0.69	2,060
1946	2,870	0.68	1,950
1947	2,786	0.68	1,900
1948	2,865	0.68	1,959
1949	2,407	0.69	1,655
1950	3,173	0.70	2,221
1951	2,989	0.71	2,132
1952	3,110	0.71	2,224
1960	4,145	0.71	2,943
1965	4,735	0.69	3,256
1970	5,430	0.66	3,565
1975	6,090	0.63	3,864

Source:
Dollar Output—Actual—U. S. Department of Commerce. Estimated—Stanford Reserch Institute.
Lumber Consumption—1933, 1940, 1947, 1948, 1951—U. S. Department of Commerce. Other years Estimated by Stanford Research Institute.
Use Factors—Derived by Stanford Research Institute.

fixtures. The increase in value of output by 1975 is expected to be partially offset by reduced use of lumber per dollar. The decline in the use factor is expected to be at a rate considerably less rapid than in the past.

Metals, fabrics, and plastics have made substantial inroads in kitchen, porch, and garden furniture because of their weather resistance and ease of cleaning. A feeling in commercial circles that wood furniture lacks a modern appearance and is less durable than metals, with resulting higher long-term costs, has caused a decline in demand for wood furniture in commercial and public buildings. The more sanitary appearance of non-wood materials and their greater durability has resulted in the displacement of wood in the professional furniture market. Major effects of such competition, however, may already have been felt.

Past and projected lumber consumption in the production of railroad freight cars and trucks and trailers are shown in Table 11.

Total lumber demand for manufactured products is expected to increase from present levels of about 5 billion board feet annually to about 5.7 billion board feet annually by 1975. The importance of the furniture and fixture industry will increase, accounting for about 68 per cent of all lumber used by manufactured products by 1975, compared to an estimated 48 per cent in 1953.

Total Lumber Consumption and Domestic Production

Table 12 summarizes the distribution of total United States lumber consumption by major end uses for 1930, 1940, 1950, and 1953, with projections to 1975. No major shifts in the broad pattern of lumber use are apparent, despite the internal shifts within categories. Total lumber consumption in the United States is expected to increase moderately from 41.3 billion board feet in 1953 to 44.6 billion in 1975.

Domestic production of lumber will, of course, differ from total consumption because of net imports and re-use

Table 11.—UNITED STATES CONSUMPTION OF LUMBER IN RAILROAD FREIGHT CAR PRODUCTION AND IN TRUCK AND TRAILER PRODUCTION,[1] 1932–1975

(Millions of Board Feet)

Year	Auto and Box Cars	Gondolas	Reefers	Others	Freight Car Totals	Lumber Consumption in Trucks and Trailers
1932	6.1	1.7	0.8	2.4	11.0	
1933	6.9	0.04	0.5	---	7.4	
1934	39.7	23.1	4.2	4.0	71.0	
1935	4.3	10.3	3.4	0.1	18.1	
1936	75.2	35.7	23.3	3.2	137.4	
1937	118.7	61.9	24.2	6.3	211.1	
1938	30.0	11.2	1.4	4.1	46.7	
1939	41.0	19.9	1.0	2.3	64.2	
1940	106.5	53.6	5.2	3.9	169.2	
1941	156.6	54.0	12.1	4.6	227.3	
1942	114.9	41.7	4.5	7.9	169.0	
1943	5.6	43.6	0.1	5.7	55.0	
1944	68.7	35.7	2.6	5.2	112.2	
1945	77.8	29.3	8.5	4.3	119.9	
1946	66.4	34.5	7.0	1.5	109.4	
1947	107.2	40.9	40.2	2.5	190.8	
1948	135.1	92.5	44.5	2.8	274.9	
1949	51.7	99.6	42.7	6.6	200.6	
1950	71.1	24.2	13.7	6.4	115.4	128
1951	129.3	61.6	25.7	7.8	224.4	135
1952	-----	--	---	- -	-----	116
1960	67.9	43.2	17.3	3.8	132.2	140
1965	58.2	40.0	15.7	3.2	117.1	151
1970	49.1	36.0	14.8	2.7	102.6	167
1975	40.9	35.5	14.2	2.5	93.1	183

[1] Does not include house trailers.
Source: Stanford Research Institute.

Table 12.—ESTIMATED DISTRIBUTON OF UNITED STATES LUMBER CONSUMPTION BY MAJOR END USES, 1930–1975

(Millions of Board Feet)

Year	Construction	%	Shipping	%	Manufactured Products	%	Total	
1930	20,346	70.9	5,100	17.8	3,260	11.3	28,706	100
1940	27,899	76.5	5,500	15.1	3,073	8.4	36,472	100
1950	32,139	75.0	6,035	14.1	4,656	10.9	42,830	100
1953	29,929	72.4	6,350	15.4	5,036	12.2	41,315	100
1960	29,122	71.5	6,580	16.2	5,000	12.3	40,702	100
1965	29,338	70.9	6,830	16.5	5,220	12.6	41,388	100
1970	30,459	70.6	7,170	16.6	5,500	12.8	43,129	100
1975	31,628	70.9	7,330	16.4	5,690	12.7	44,648	100

Source: Stanford Research Institute.

Table 13.—ESTIMATED DOMESTIC LUMBER PRODUCTION BY REGION AND SPECIES, 1952–1975

(Billions of Board Feet)

	1952	1960	1965	1970	1975
U. S. Consumption	40.7	40.7	41.4	43.1	44.6
Net Imports	1.8	1.0	0.4	1.4	1.2
Reused Lumber	0.5	0.8	1.0	1.2	1.4
U. S. Production	38.4	38.9	40.0	40.5	41.0
Softwoods	30.5	30.8	31.7	32.1	32.5
Hardwoods	7.9	8.1	8.3	8.4	8.5
East	5.1	5.1	5.1	5.2	5.2
Softwoods	2.0	2.0	2.0	2.0	2.0
Hardwoods	3.1	3.1	3.1	3.2	3.2
South	13.7	13.9	14.0	14.1	14.3
Softwoods	9.0	9.0	9.0	9.0	9.0
Hardwoods	4.7	4.9	5.0	5.1	5.3
West	19.6	19.9	20.9	21.2	21.5
Softwoods	19.5	19.8	20.8	21.1	21.4
Hardwoods	.1	.1	.1	.1	.1

Source: Stanford Research Institute.
Note: Detail may not add to total, due to rounding.

of lumber salvaged from earlier uses. Table 13 shows both consumption and production of lumber for 1952 and the probable levels for 1960, 1965, 1970, and 1975. Also shown in Table 13 are the estimated levels of production by regions, divided between softwoods and hardwoods. As indicated in an earlier section, increased production of softwood lumber in the West and of hardwood lumber in the South are likely to be the only significant changes in domestic lumber production between 1952 and 1975.

The Demand for Pulp and Pulpwood

The largest consumer of wood pulp is paper. In 1953, the total output of paper was about the same as paperboard, but the wood-pulp requirements per ton of product were almost twice as great. As a result, about 54 per cent of all wood pulp consumed was taken by the paper industry, as compared with about 33 per cent by the paperboard industry. Wood pulp requirements for building papers and building boards, not included in the above figures, represented almost 9 per cent of total wood pulp consumption. The remaining 4 to 5 per cent of wood pulp consumption is attributed to dissolving pulp uses.

Paper and Paperboard

Paper and paperboard consumption estimates are shown in the table below, built up from estimates of consumption of individual types of each:

Product	Millions of Tons				
	1952	1960	1965	1970	1975
Total Paper	16.9	20.8	23.3	25.8	28.0
Total Paperboard	12.1	16.6	19.4	22.1	24.9
Total Paper and Paperboard	29.0	37.4	42.7	47.9	52.9

Paper consumption, as measured by new supply (production plus imports, less exports), increased about 93 per cent between 1929 and 1953, rising from 9.1 to 17.6 million tons. Consumption of all papers by 1975 is estimated at about 28 million tons, base on correlation with population, real disposable income, and trend; this checks reassuringly with the total estimates for each of the paper types.

To arrive at an estimate of production requirements in the United States in each of the future years, it is necessary to make allowances for net imports of paper and paperboard. In 1952, net imports totalled 4.6 million tons, with newsprint imports of 5 million tons partially offset by net exports of other grades. Heavy imports of newsprint are expected to continue; this country will remain a net importer of paper and paperboard. Net imports are estimated to reach about 6.3 million tons by 1975.

Total domestic production of paper and paperboard is expected almost to double, from 24.4 million tons in 1952 to 46.6 million tons by 1975. A summary of this production, by major paper and paperboard categories, is shown in the following table:

Domestic Production of Paper and Paperboard
(Millions of Tons)

Grade	1952	1960	1965	1970	1975
Total Paper	10.9	13.6	15.4	17.1	19.0
Fine	1.3	1.6	1.8	2.0	2.3
Newsprint	1.1	1.3	1.5	1.6	1.7
Book and other printing	3.4	4.2	4.8	5.4	6.0
Coarse	3.2	3.8	4.2	4.6	5.0
Sanitary, tissue and other	1.9	2.7	3.1	3.5	4.0
Total Paperboard	10.9	14.5	16.8	19.0	21.3
Containerboard	5.8	7.4	8.5	9.6	10.7
Boxboard and other	5.1	7.1	8.3	9.4	10.6
Building Paper and Paperboard	2.6	3.9	4.7	5.5	6.3
Building paper	1.3	1.8	2.1	2.4	2.7
Building board	1.3	2.1	2.6	3.1	3.6
Totals	24.4	32.0	36.9	41.6	46.6

Pulp Uses other than Paper and Paperboard

Of the 800,000 tons of wood pulp used in products other than paper and paperboard in 1952, the most important consuming industry was rayon and acetate, which took 61 per cent. The remaining 39 per cent was used for cellophane, lacquers, photographic film, plastics, and explosives.

Most important growth area in the rayon and acetate industry has been in high-tenacity filament yarn. This growth has been greatly due to the tire cord and fabric market. From less than 1 per cent of this market in 1937, high-tenacity rayon rose to 64 per cent by 1950, and two years later it had taken about 77 per cent.

Textile consumption of rayon and acetate declined in the latter part of 1953, reflecting not only growing competition from other man-made fibers, but also from cotton, which is gaining an increasing share of the apparel market as a result of new finishes and dyes. It is expected by 1975 rayon and acetate will be about 23 per cent of mill consumption of fibers, compared with 18.9 per cent in 1952. This indicates a declining rate of growth for rayon and acetate in the textile industry.

Wood pulp consumption in other products has increased from about 70,000 tons in 1939 to about 308,000 tons in 1952. It is estimated total pulp consumption in these other uses will increase to about 600,000 tons by 1975.

Total non-paper uses of wood pulp are expected to increase from 800,000 tons in 1952 to about 1,800,000 by 1975.

Wood Pulp Requirements

Wood pulp needed to produce the paper and paperboard shown on the previous page, together with quantities required for the production of other products, was estimated on both statistical and qualitative bases. All estimates provided similar answers, although the qualitative estimates, based on a detailed evaluation of each of the producing industries, were used for this study.

The qualitative estimate, based on the probable composition of the furnish[5] per ton of each of the major

[5] Furnish: The mixture of materials from which paper or board is made, chiefly fibrous material (pulp), sizing materials, fillers and dyes.

ESTIMATED CONSUMPTION OF WOOD PULP IN THE UNITED STATES

(Millions of Tons)

Estimated Consumption of Wood Pulp in the United States
(Millions of Tons)

Product and Type of Pulp	1952	1960	1965	1970	1975
For paper, paperboard and building materials					
Total	17.2	23.1	26.8	30.3	34.3
Unbleached sulphate	6.3	7.4	8.2	9.1	10.0
White pulps[a]	6.3	8.7	9.2	9.9	10.7
Groundwood	2.6	3.5	4.1	4.6	5.1
Defibrated or exploded	1.1	1.7	2.5	2.6	3.1
Semi-chemical	0.8	1.6	2.6	3.9	5.2
Screenings, damaged, etc.	0.1	0.2	0.2	0.2	0.2
For all other products[b]	0.8	1.2	1.4	1.5	1.8
Totals	18.0	24.3	28.2	31.8	36.1

[a] White pulps include bleached and unbleached sulphite, bleached and semi-bleached sulphate and soda pulps.
[b] Primarily alpha and dissolving pulps.

classes of paper and paperboard for each of the target years, shows that by 1975, 36.1 million tons of wood pulp will be consumed in all products, with 34.3 million tons required for the production of paper and paperboard alone. A detailed breakdown of wood pulp consumption by type of pulp and by use is shown below:

The following tabulation shows the steps involved for computation of domestic pulpwood requirements for 1952 and each of the target years:

(Millions of Cords, Roughwood Basis)

	1952	1960	1965	1970	1975
Pulpwood equivalent of wood pulp consumed	29.5	38.9	44.1	48.9	54.8
Pulpwood equivalent of imports of wood pulp	3.0	4.1	4.7	5.3	6.0
Pulpwood consumed in U. S.	26.5	34.8	39.4	43.6	48.8
Net imports of pulpwood	2.0	1.4	1.3	1.3	1.3
Requirements for domestic pulpwood	24.5	33.4	38.1	42.3	47.5

Domestic Pulpwood Sources by Region

The changes from 1952 to 1975 can be summarized as follows:

(Millions of Cords, Roughwood Basis)

Type of Wood	East	South	West	Total U. S.
Increase in softwood logs and bolts	—0.4*	6.8	1.1	7.5
Increase in hardwood logs and bolts	.23	5.3	...	7.6
Increase in mill residuals	0.9	3.4	3.6	7.9
Total increase in pulpwood supply	2.8	15.5	4.7	23.0

*Decrease.

Although softwood logs and bolts accounted for 80 per cent of domestic pulpwood production in 1952, they account for only about a third of the expected increase in total pulpwood production between 1952 and 1975. Most of the increase in softwood logs and bolts is expected in the South, reflecting the large forest holdings being developed by the pulp companies and the fast growth of pulping species.

The expected increased production of hardwood logs and bolts in the East and South reflects the new pulping process to utilize hardwoods, the relative abundance of hardwood supplies in these regions, the importance of utilizing the whole forest crop in managed forests, and the expected reduction of imports of Canadian pulpwood in the East.

The six-fold increase in the use of mill residuals, from 1.5 million equivalent cords in 1952 to 9.4 million in 1975, is based on the potential supply of chippable material, and the probable economic feasibility of using it, in each region.

The potential annual supply of chippable material in the East between now and 1975 is estimated at about the equivalent of 2 million cords based on annual lumber production of 3.1 billion board feet of hardwoods and 2 billion board feet of softwoods under present industry organization. This is shown below:

From Eastern Sawmills with Annual Production of:	Yield of Chippable Material (Thousands of Equivalent Standard Cords, Roughwood Basis) Softwoods	Hardwoods
Over 10 million board feet	50	70
5 to 9.9	50	70
1 to 4.9	270	400
Less than 1	500	700
Total	870	1,240

The following table of potential supply of chippable material in the South during the early 1960's is based on expected annual production of 9 billion board feet of softwood lumber and 5 billion board feet of hardwood lumber, distributed among mills by size essentially as at present:

From Southern Sawmills with Annual Production of:	Yield of Chippable Material (Thousands of Equivalent Standard Cords, Roughwood Basis) Softwoods	Hardwoods
Over 10 million board feet	520	250
5 to 9.9	490	250
3 to 4.9	380	200
1 to 2.9	1,040	540
Less than 1	1,660	810
Total	4,090	2,050

Because a large number of small mills in the South produce lumber from small logs, chip utilization has been insignificant in the South. The possible availability of whole-log barkers that will be economically feasible for mills with capacities as low as 20,000 board feet per day (about 5 million per year) may make possible the utilization of a larger quantity of chippable material. Efforts are also being made to concentrate slabs with bark at pulpwood shipping points in the South for mass transportation to pulp mills. Although the small size of slabs has made the development of economical slab barkers difficult, such debarking appears feasible under some conditions. Separation of bark from the chips may also prove technically feasible, despite early disappointments with flotation systems.

On a regional basis, the chippable material potential in the West is located as follows:

1. In the Douglas fir region of western Washington and Oregon, with an assumed annual lumber output of 10 billion board feet, 4.33 million cords are assumed to be available, plus an additional .33 million cords of pulp chips from the production of 3 billion square feet ($\frac{3}{8}$-inch equivalent) of plywood. About 40 per cent of this material is produced in southwest Oregon, where there is little present pulp production capacity.
2. In the California pine and redwood regions, with an assumed annual lumber output of 5 billion board feet, 2.15 million cords of chippable material may be expected.
3. In the remainder of the West, including eastern Washington, eastern Oregon, and the Rocky Mountain area, with an assumed lumber output of 5 billion board feet annually, 2 million cords of chippable materials are estimated.

At present, most of the more economical sources of chips have been brought into use, although some further increases of chips from existing sources can be obtained through additional barker installations. It is believed that the most important source of additional chip use in the West will be attained through additional pulp capacity in other lumber-producing areas within the region.

It is probable that any substantial increase in residual utilization in the West over the 5 million cords estimated for 1975 could be attained only at rapidly rising costs. Furthermore, the achievement of this level depends on the location of new pulping capacity in the lumber-producing areas not now serving pulp mills.

The Demand for Plywood, Veneer and Building Boards

Demand for veneers and plywood is chiefly from the construction and shipping containers industries, with the remainder going into a wide variety of manufactured products. About two-thirds of the veneer is used to manufacture plywood, of which about 50 per cent is used in residential and nonresidential construction of all types

Demand for Plywood in Construction

The use of plywood (primarily softwood plywood) in new residential building can be summarized as follows:

(Millions of Square Feet)

Year	Foundations	Floors	Ceilings and Interior Walls	Roofs	Exterior Walls	Millwork, Accessory Buildings, and Miscellaneous	Total	
							Square Feet	3/8" Equivalent
1[illegible]	--	- -	27.7	----	----	6.6	34.3	48.0
1930	---	4.2	22.2	9.7	3.0	7.8	46.9	65.7
1940	2.7	52.3	31.6	25.5	9.7	21.9	143.7	201.2
1950	7.2	188.0	65.9	58.4	82.6	56.3	458.4	641.8
1953	5.6	184.1	52.0	398.9	244.6	128.6	1,013.8	1,419.2
1960	7.2	236.3	108.5	492.9	265.1	161.0	1,271.0	1,779.4
1965	7.2	239.1	119.1	567.4	294.5	178.0	1,405.3	1,968.0
1970	7.2	251.1	189.9	673.3	317.8	208.0	1,647.3	2,306.2
1975	7.2	254.2	211.2	779.1	308.3	226.0	1,786.0	2,500.4

These estimates were derived in the same way as the lumber estimates in the section on lumber demand.

The growth in residential use of plywood was aided by the development in 1934 of exterior-grade plywood for exterior walls. It has since found great popularity among builders of prefabricated houses. At present, about 40 per cent of the plywood used in new residential construction is for roof sheathing, about 25 per cent for sheathing and facing of exterior walls and about 18 per cent for floor underlay. The use of plywood in roof sheathing has increased rapidly in the past few years, and this material now represents about a quarter of the roof sheathing market.

Almost all the use of plywood in exterior walls is for sheathing, with a minor quantity being used as facing, generally in prefabricated houses. The heavy demand for plywood as an underlay material for linoleum and tiles in residential construction is expected to increase at a less rapid rate in the future because the greater use of slab-type construction reduces the need for underlayment.

Plywood consumption in nonresidential construction has also increased at a rapid rate. In 1951, a reported 148 million square feet of plywood were used, including about 11 million square feet for farm service buildings. A considerable quantity of hardwood plywood is also used in nonresidential building for interior panelling.

The most important requirement for plywood in non-residential construction is for use in concrete forms to provide large, smooth finished surfaces, so finishing time can be reduced. It is estimated that, of all plywood used in non-farm nonresidential construction, about 83 per cent is for forms, about 12 per cent for cabinets and trim, about 3 per cent for interior wall panelling, and the remaining 2 per cent for miscellaneous purposes.

Plywood for concrete forms faces competition from steel and hardboard, but it is expected that plastic facing on plywood and other product improvements will tend to keep a plywood a strong contender.

Plywood for maintenance and repair now exceeds 15 per cent of the total plywood supply, and it is likely that this market will expand considerably through the do-it-yourself trend.

Demand for Plywood and Veneer in Shipping Containers

Veneer in shipping containers is used for baskets and hampers, wirebound boxes, and plywood containers. The latter represent about a fourth of the veneer consumption in containers. Veneer is preferred for shipping fruits and vegetables because of its strength and light weight, which cuts shipping costs.

Competition from paperboard, which has been moving rapidly into the produce container market in the past few years, is expected to be met successfully by the introduction of the kraft-veneer container. This container offers strength in the presence of moisture not equalled by paperboard.

Demand for Plywood and Veneer in Manufactured Products

Plywood and veneer are used for wide surfaces of furniture or fixtures, with plywood often providing working surface for the application of the fancy facing veneers. Plywood and veneer are used in such products as radio and television cabinets, dressers (fronts, sides, and tops), chairs, and tables. In the fixtures field, these products are used for counters, cabinets, and showcases; their availability in large panels has aided the growth of plywood and veneer in the fixtures field.

In the furniture segment, about four times as much hardwood veneer is used as softwood, and in the fixtures segment about twice as much softwood veneer as hardwood. Among the most popular hardwoods used as face veneers are gum, tupelo, birch, basswood, black walnut, yellow poplar, mahogany, and oak.

Based on the outlook for furniture and fixtures production, it is estimated that by 1975 about 2.25 billion square feet of plywood can be consumed by the furniture and fixtures industry.

Plywood and veneer are used in a multitude of manufactured products besides furniture. Some of the more important industries using plywood and veneer are the housetrailer, motor vehicle, trunk and valise, ship and boat building, musical instrument, electrical equipment, aircraft, sporting goods, game and toy industries. It appears likely that plywood consumption in this miscellaneous group will keep pace with the output of these products; therefore a consumption of about 750 million square feet in 1975 appears reasonable.

Total Demand for Plywood and Veneer

Total veneer production is expected to increase from about 19.3 billion square feet in 1951 to about 34.5 billion square feet by 1975. Production of softwood plywood in that year is expected to total about 7.2 billion square feet (3/8-inch equivalent) and production of hardwood plywood about 2 billion square feet.

Demand for Building Boards (Insulating Board and Hardboard)

Because building boards compete with plywood, their demand is discussed here, even though material requirements for building boards are included under paperboard.

Consumption of building board, as indicated by changes in new supply, has increased more than ten-fold since 1929, which the bulk of the increase coming since the beginning of World War II. The greatest relative increase has been in hardboard; about 16 times as much hardboard was consumed in 1953 as in 1929. Insulating board has also shown a healthy 700 per cent increase during the same period.

Insulating Board Demand

Insulating board, which is known also as structural or rigid insulation, is produced from wood fiber and sugar cane bagasse. It is used as a facing material for interior walls and ceilings in a variety of forms including planks, tileboard, and sheets; it is also used on exterior walls a a sheathing material, or in some cases as an exterior facing material.

As an exterior wall sheathing material, insulating board accounted for about a quarter of the residential exterior wall sheathing market in 1953. In 1920, it accounted for only about 4 per cent of this market. It is expected, because of the cost advantages of insulating board, that its share will rise to about 34 per cent by 1975, largely at the expense of lumber.

Insulating board as a facing material for interior walls and ceilings is used in new residential construction, for maintenance and repair of residential construction, and in nonresidential building. In new residential construc-

tion, as reported by residential contractors in 1953, insulating board was used on about 2 per cent of the interior wall and ceiling areas. This represents a decline from an estimated 7 per cent of the ceiling facing market in 1929 and 3 per cent of the interior wall facing market in the same year. For the additions and alterations market, however, it is easily handled by the amateur and provides a low-cost facing material for such uses as the conversion of attic space to usable living area.

Hardboard Demand

Hardboard is distinguished from insulating board by greater density and rigidity, harder surface, and greater resistance to impact. Its production has steadily increased.

The following tabulation shows the available information on hardboard use, with projections to 1975:

(Millions of Square Feet—1/8" Equivalent)

Year	Construction	Furniture	Manufacturing	Household	Total
1926	n.a.	n.a.	n.a.	n.a.	5
1929					75
1933					70
1937					254
1941					365
1945					550
1947					745
1948					957
1949					533
1950					916
1951					801
1952	218	325	282	175	1,000
1960	531	425	400	240	1,596
1965	773	530	460	270	2,033
1970	1,003	650	570	330	2,553
1975	1,280	780	630	360	3,050

Note: "n.a." indicates not available.
Source: Actual— U. S. Department of Commerce and Stanford Research Institute. Estimates—Standford Research Institute.

Hardboard is used by the furniture and fixtures industry to an increasing extent in drawers, dresser backs, under plastic surfaces in dinette sets, and for table tops in inexpensive furniture built for hard wear. In the fixtures segment of the industry, it is widely used for displays, counters, and partitions.

Hardboard is being used more by the construction industry—both residential and nonresidential—because of its relatively low cost and adaptability to many uses. Estimates of the consumption of hardboard in new residential construction are given as follows:

(Millions of Square Feet)

Year	Floors	Ceilings	Roofs	Interior Walls	Millwork, Accessory Buildings and Miscellaneous	Square Feet	1/8" Equivalent
1950	25.0				3.5	28.5	34.1
1953	15.7	23.0	17.0	41.6	14.1	111.4	126.9
1960	43.7	53.3	37.9	95.2	33.4	263.5	298.4
1965	59.8	87.6	63.9	156.8	53.2	421.3	476.1
1970	60.5	114.0	92.7	231.5	72.2	570.9	644.6
1975	67.8	144.8	131.1	321.8	96.6	762.1	850.0

As an underlay material in new residential construction, hardboard accounted for about 2 per cent of the market in 1953. It is expected that by 1975 hardboard will have about 8 per cent of this market, in the face of stiff competition from plywood.

From about 1 per cent of the interior wall surfacing market in 1953, hardboard is expected to reach 5 per cent by 1975; in the ceiling surfacing use, hardboard is expected to increase from the present 2 per cent to 8 per cent of the market. Gains are also expected in the use of hardboard as roof sheathing and for doors, cabinets, and trim.

Hardboard in nonresidential construction is largely used for concrete forms and interior partitions forming permanent parts of a building. On the farm, hardboard is adapted to many uses, such as exterior wall covering, partitions, and bins. With hardboard expected to gain relative price advantages and enjoy continued product improvement, it is expected that the use of hardboard per dollar of nonresidential construction will continue to increase, and that by 1975 about 350 million square feet of hardboard might be consumed by nonresidential construction, as compared with slightly more than 100 million in 1952.

In manufactured products also, hardboard has become increasingly popular in motor vehicle bodies, signs, toys and play equipment, electrical panels, aircraft die stock, and a multitude of other products. It is likely hardboard usage will continue to increase more rapidly than the growth of these using industries themselves. Based on these factors and the estimated increase in industrial production discussed earlier, it is estimated that hardboard consumption in manufactured products might reach 630 million square feet by 1975.

In the do-it-yourself market, hardboard use is expected to be big. Suitable for interior walls and ceilings, closet doors, furniture, work surfaces, portable partitioning, shelving, and many other uses, hardboard can readily be installed by amateurs, and it wears well. From about 210 million square feet in 1953, home consumption of hardboard can be expected to increase to about 360 million square feet by 1975.

Total hardboard consumption in all uses is expected to increase from present levels of about 1.2 billion square feet to about 3 billion square feet by 1975.

The Demand for Other Forest Products

In addition to lumber, plywood, and pulp products, a number of other forest products account for the balance of timber use. Chief among these are fuelwood, shingles and shakes, cooperage, piling, poles, wood for distillation and charcoal and a large number of miscellaneous uses. Fuelwood is the most important in terms of wood requirements.

Fuelwood

No reliable data exist on past supply and consumption of fuelwood because of the ubiquitous nature of the product and the lack of an organized fuelwood industry. Estimated United States consumption of fuelwood is summarized on next page.

Shingles and Shakes

Demand for shingles and shakes is largely derived from new residential construction activity; in 1950 this market accounted for about 60 per cent of total United States shingle and shake consumption. Based on an estimated 5 per cent of the total roof market and about 10 per cent of the exterior facing market in new frame residential construction (reflecting consumer preference in construction of the more expensive homes), consumption of wood shingles and shakes in new residential construction is estimated to be about 2.8 million squares. Total consumption is estimated at 4.5 million squares, of which only 2 million are expected to be produced domestically, with 2.5 million imported from Canada.

Slack Cooperage

Markets for slack cooperage include dry bulk terms such as food (powdered milk, meat, poultry, and sea foods), hardware (nails, rivets, and bolts), tobacco and chemicals, including dry soaps and detergents.

Increasing competition from fiber drums, cotton bags, burlap bags, and paper sacks have cut deeply into the

(Millions of Cords)

Year	Heat Rural Farm	Heat Rural Nonfarm	Heat Urban	Fireplace	Other	Total
1940	38.2	16.6	9.4	12.0	3.1	79.3
1950	20.6	13.0	5.8	14.0	1.6	55.0
1960	7.5	9.3	2.4	14.0	0.6	33.8
1965	4.4	5.8	2.4	15.0	0.4	28.0
1970	2.9	4.3	2.4	16.0	0.2	25.8
1975	2.3	3.7	2.4	17.0	0.2	25.6

slack cooperage market. Production of slack cooperage declined from about 55 million barrels in 1929 to about 28 million in 1952.

Based on the estimated share of the total bag-and drum-type shipping container market expected to be taken by slack cooperage (earlier reference), an additional 40 per cent decline, to around 17 million barrels, is expected by 1975.

Tight Cooperage

The major demand for tight cooperage is for the storage of whiskey and, to a lesser extent, other alcoholic beverages. Other products important to the tight barrel industry are foods (condensed milk, pork and lard, and brined meat), and chemicals.

The failure of the tight cooperage industry to maintain production, which has slumped by about 78 per cent from 1929 levels, is the result of stiff competition from steel and fiber drums, as well as the development of other means of handling bulk liquid shipments, such as tankers and pipe lines.

Piling

Major uses of piling are in marine construction for wharves and piers, in heavy land construction in swampy areas or in marginal lands to provide firm foundations for large structures, and for the construction of trestles and bridges. The lower cost of wood piling as compared to steel and concrete, or a combination of steel and concrete, is the predominant factor in the use of wood piling.

Projections of treated piling production based on past trend, with war years and depression years omitted, indicate that production of treated piling in 1975 might well be in the neighborhood of 15.5 million cubic feet. With an expected increase in the ratio of treated piling to total piling from present levels of about 60 per cent to about 67 per cent by 1975, a total piling production of about 23 million cubic feet would be forthcoming on this basis in 1975.

Poles

At present, there are about 30 million poles in use for communication lines; about 40 per cent of these are shared with electric power companies. There are an additional 50 million poles now in service for the distribution of electric power exclusively. Most of the poles now in service are treated or are reinforced with treated stubs; their average life is estimated at about thirty years.

In addition to replacement demand, new demand for poles will rise as rural electrification is extended and as a result of new residential construction in new areas. Demand for wooden poles will tend to be reduced by underground installations of communication lines and the shift to steel towers for power transmission lines.

On balance, it is expected that pole production will increase from about 103 million cubic feet in 1952 (for about 5.9 million poles, of which 5.3 million were treated), to about 128 million cubic feet in 1975.

Wood for Distillation of Charcoal

The recovery of volatile constituents, including acetic acid, methanol, and acetone, formed the basis of the hardwood distillation industry, but stiff competition from production of the same chemicals from coal and petroleum has left charcoal as the primary product of hardwood distillation. Consumption of distillation wood is expected to increase from about 500,000 cords in 1952 to about 600,000 cords by 1975, primarily as a result of increased charcoal demand.

Miscellaneous Forest Products

In addition to the major uses of wood and wood products outlined in previous sections, an indeterminate amount of wood is used for various other products.

Use of wood for the production of chemicals, other than wood used in distillation, is of minor importance as a demand for timber, since it utilizes almost entirely forest and mill residuals and pulping liquors. Turpentine, for example, is essentially a forest industry by-product, utilizing stumps, top wood, and waste sulphate pulping liquors. Tall oil, another wood chemical, is a by-product of the kraft pulping industry and is used in the manufacture of soaps and detergents, surface coatings, linoleum, chemicals, and other products. It would appear that a consumption of 250 million cubic feet of wood annually (between 2 and 3 per cent of total wood use) for miscellaneous uses is reasonable.

Log and Bolt Requirements

Because the conversion of forest products demands to their equivalent log and bolt requirements necessarily entails technical discussion, this section will present first the points of general interest summarizing the results of the computations. These will be followed by tabulations showing the conversion factors used and the computations of log and bolt requirements for each product, which may be of particular interest to technically trained readers.

The conversion of end-product demands for forest products to the volumes of logs and bolts required for their production involves the following steps:

Total consumption of end products
- Less—net imports and re-use of end products
- Equals — domestic production of end products

Domestic production of end products
- Times—Conversion factors
- Equals—Domestic consumption of logs and bolts

Domestic consumption of logs and bolts
- Less—imports of logs and bolts
- Less—utilization of mill residues
- Equals — Domestic log and bolt requirements

Domestic log and bolts requirements
- Less—logs and bolts used below minimum scaling standards
- Equals—Domestic logs and bolts of scalable size

The figures for log and bolt requirements in this study are for logs and bolts of scalable size (that is, above minimum scaling standards) required at mill sites.

The quantity of logs and bolts estimated as being required for lumber and other forest products that are expected to be produced in this country in future years is not directly comparable with "requirements" shown in other studies of this general type.

Log and bolt requirements in this study will tend to be higher than those in other studies, in that requirements in this study include logs and bolts cut from dead trees. For example, in 1952 in Oregon and Washington, 1.8 billion board feet of logs were cut from dead timber, representing 12.8 per cent of the total volume of logs cut in the two states. This study, unlike others, also includes logs from species considered as "noncommercial" by the U. S. Forest Service as well as logs from areas not classified as "commercial forestland" by the Forest Service.

On the other hand, log and bolt requirements in this study will tend to be lower than those in other studies in that requirements in this study include only logs and bolts needed at the mill deck, omitting the portion of live timber cut that is left in the forest. Therefore, this study does not purport to estimate the drain on the timber inventory.

The following tabulation shows the beginning and ending of the conversion procedure discussed at the start of this section, from consumption of end products to domestic logs and bolts of scalable size required for their production, for 1952 and 1975:

				Log and Bolt Requirements (Billions)			
		Consumptions		Board Feet[1]		Cubic Feet	
End Product	Unit	1952	1975	1952	1975	1952	1975
Lumber—Total	Billion board feet (lumber tally)	40.7	44.6	36.4	37.4	5.87	6.82
Softwood		32.2	35.2	28.9	29.6	4.64	5.36
Hardwood		8.5	9.4	7.5	7.8	1.23	1.46
Softwood Plywood and Veneer	Billion Sq. Ft. (3/8")	3.3	7.5	1.6	3.7	0.24	0.56
Hardwood Plywood and Veneer	Billion Bd. Feet, Local log scales	1.0	1.4	1.2	1.7	0.18	0.24
Pulpwood—Total	Million cords (roughwood basis)	26.5	48.8	4.3	4.9	1.76	2.81
Softwood		22.8	36.1	3.9	3.9	1.50	2.00
Hardwood		3.7	12.7	0.4	1.0	0.26	0.81
Shingles and Shakes	Million squares	3.0	2.0	0.2	0.2	0.05	0.03
Cooperage	Million Bd. Ft. Lbr. Equiv.	504	390	0.5	0.4	0.07	0.06
Piling	Million Cu. Ft.	28	23	0.2	0.1	0.03	0.03
Poles	Million Cu. Ft.	103	128	0.6	0.7	0.11	0.14
Fuelwood[2]	Million Cords	50	26	2.9	0.6	1.31	0.37
Wood for Distillation and Charcoal	Thousand Cords	500	600	[3]	[3]	0.04	0.04
Mine timbers (not sawn)	Million Cu. Ft.	100	100	0.2	0.2	0.10	0.10
Railroad ties (hewn)	Million pieces	15.8	13.7	0.6	0.5	0.10	0.09
Miscellaneous	Million Cu. Ft.	250	250	0.4	0.4	0.25	0.25
Totals				49.1	50.8	10.11	11.54

[1] International ¼" log scale.
[2] Log and bolt requirements from living commercial timber only.
[3] Less than 0.05.

The relationship between board foot and cubic foot volumes varies with the size of material used, as will be shown in detail later. The supporting details of the computations for each product are also shown later in this section.

Domestic requirements for sawlog-size material, expressed in board feet, are expected to increase by only 1.7 billion board feet, or about 3.4 per cent, between 1952 and 1975. Increases in requirements for lumber, plywood and veneer, pulpwood and poles are expected to be partially offset by reduced requirements for fuelwood, cooperage, piling, and hewn railroad ties.

Domestic requirements for all scalable timber, expressed in cubic feet, are expected to increase by 1.43 billion cubic feet, or about 14 per cent, between 1952 and 1975. This relatively greater increase in cubic volume, as compared to board foot volume, reflects in part the expected increased relative importance of pulp, and in part the expected continued trend toward use of smaller logs, many of them below sawlog size but still scalable in cubic volume. Even within sawlog grades, cubic foot requirements tend to increase rapidly with a decline in average log size. Cubic foot requirements per thousand board feet of lumber output, for example, are expected to increase from 154 in 1952 to 166 by 1975.

The relative importance of the major end product groups as a percentage of total log and bolt requirements in 1952 and 1975 is shown in the following tabulation:

	Percentage of Total Log and Bolt Requirements			
	Sawtimber Only (Based on Board Feet)		All Timber (Based on Cubic Feet)	
Product	1952	1975	1952	1975
Lumber	74%	74%	58%	59%
Pulpwood	9	10	17	24
Plywood and Veneer	6	11	4	7
Fuelwood	6	1	13	3
All Others	5	4	8	7
Total	100%	100%	100%	100%

A summary of log and bolt requirements in cubic feet by regions and products for 1952 and 1975 is shown below:

(Billions of Cubic Feet)

	South		East		West		Total U. S.	
Product	1952	1975	1952	1975	1952	1975	1952	1975
Lumber	2.30	2.66	0.82	0.93	2.75	3.23	5.87	6.82
Pulpwood	1.08	1.92	0.43	0.56	0.25	0.33	1.76	2.81
Plywood and Veneer	0.11	0.14	0.07	0.10	0.24	0.56	0.42	0.80
Fuelwood	0.71	0.19	0.53	0.15	0.08	0.04	1.31	0.37
All Other	0.39	0.39	0.22	0.21	0.14	0.13	0.76	0.74
Total	4.59	5.30	2.07	1.95	3.46	4.29	10.12	11.54

Note: Detail may not add to total, due to rounding.

It is expected that the average size and minimum size of sawlogs will decline in each region during the coming twenty years, with the result that an increase in cubic feet will be required for each board foot output of lumber. Thus, although increased yields due to technology are reflected directly by the decreased requirements measured in board feet log scale, cubic foot log requirements are heavily influenced by the rapid increases in cubic footage required per board foot of lumber output with declining log size.

In all regions it is expected that there will be a more intensive utilization practiced in logging, closer integration of logging for pulpwood with logging for lumber, and increased use of thinnings. Under these conditions, an increased use of materials below five inches in diameter (for which cubic foot volumes are not included under the standards of this study) is expected, thus resulting in some decline in the cubic foot per cord factors.

Log requirements for the production of softwood plywood, with adjustment for mills not reporting consumption of logs, are estimated at about 440 board feet log scale for each 1,000 square feet (⅜-inch equivalent) of softwood plywood produced in 1952.

It appears that the changes in quality, size, and species of logs will not be wholly offset by manufacturing improvements. Therefore, a decline in yields of about 4 per cent is foreseen through 1975.

Hardwood veneer and plywood yields are not expected to change significantly through 1975; technological advances are expected to offset declines in log quality.

Summary of Major Conclusions

1. Substantial population increases, technological advances, and increases in living standards will expand the size and activity of the United States economy by 1975.
2. This general economic expansion will result in corresponding increases in activity in construction (especially residential), shipping containers, and manufacturing.
3. Despite these expanded markets, substantial increases in the supply of lumber, either from domestic production or from imports, are likely to be forthcoming only at costs that will encourage the sub-

stitution of competing materials for lumber. The price of lumber relative to competing materials will increase, although less rapidly than in the past, and lumber will lose part of its markets.

4. The price of plywood will increase (but less rapidly than that of lumber) relative to competing materials; the prices of pulp and paper products will continue in about their present relationship; prices of hardboard and insulating board will decline.

5. Domestic production of lumber will increase only moderately by 1975, with all the increase in softwood lumber production occurring in the West, accompanied by more moderate increases in hardwood lumber production in the South and East.

6. Despite higher lumber prices, there should be a market for all the lumber produced in the United States, plus a moderately higher level of imports (primarily from Canada) and increased re-use of salvaged lumber.

7. Major increases are expected in the domestic production and consumption of pulp, paper and paperboard products, plywood and veneer, and hardboard and insulating board.

8. A major decline is probable in fuelwood consumption.

9. Only moderate changes from their 1952 levels are foreseen for the domestic consumption and production of other forest products by 1975.

10. Total domestic requirements for sawtimber delivered to millsites are expected to increase by only about 3.4 per cent between 1952 and 1975.

11. Total domestic requirements for all timber delivered to millsites, in cubic feet, will increase by about 14 per cent between 1952 and 1975.

12. Increases in the use of mill residuals to produce pulp and other fiber products will be substantial in the West and South, but less pronounced in the East.

13. Improved pulping methods will result in greater use of hardwoods, particularly in the South and East.

14. The major increases in timber use in the South will be for pulp and for hardwood lumber; in the West, for softwood lumber and plywood, with mill residuals for increased pulp and hardboard. The East will show moderate increase for lumber and pulp.

ESTIMATED CONSUMPTION OF, AND WOOD REQUIREMENTS FOR, TIMBER PRODUCTS

Product	Unit of Measure	Quantity	Consumption					Log and Bolt Requirements (Billions)								
								1952		1960		1965		1970		1975	
			1952	1960	1965	1970	1975	Board Feet[1]	Cubic Feet	Board Feet[1]	Cubic Feet	Board Feet[1]	Cubic Feet	Board Feet[1]	Cubic Feet	Board Feet[1]	Cubic Feet
Lumber	Board Feet (Lumber Tally)	Billion	40.7	40.7	41.4	43.1	44.6	36.4	5.87	36.5	6.01	37.1	6.35	37.3	6.64	37.4	6.82
Hardwood			8.5	8.5	8.7	9.0	9.4	7.5	1.23	7.6	1.26	7.6	1.31	7.7	1.39	7.8	1.46
Softwood			32.2	32.2	32.7	34.1	35.2	28.9	4.64	28.9	4.75	29.5	5.04	29.6	5.25	29.6	5.36
Softwood, Plywood and Veneer	Square Feet (3/8")	Billion	3.3	4.6	5.5	6.6	7.5	1.6	0.24	2.2	0.33	2.6	0.40	3.2	0.48	3.7	0.56
Hardwood, Plywood and Veneer	Board Ft., Local L. S.	Billion	1.0	1.1	1.2	1.3	1.4	1.2	0.18	1.3	0.19	1.4	0.20	1.5	0.22	1.7	0.24
Pulpwood	Cords (Roughwood Basis)	Million	26.5	34.8	39.4	43.5	48.8	4.3	1.76	5.3	2.29	5.1	2.45	4.9	2.60	4.9	2.81
Pulp Total	Tons (Air Dry)	Million	18.0	24.3	28.2	31.8	36.1										
Unbleached Sulfate	Tons (Air Dry)	Million	6.3	7.4	8.2	9.1	10.0										
White Pulps	Tons (Air Dry)	Million	6.3	8.7	9.2	9.9	10.7										
Groundwood	Tons (Air Dry)	Million	3.5	4.1	4.6	4.6	5.1										
Defibrated and Exploded	Tons (Air Dry)	Million	1.1	1.7	2.5	2.6	3.1										
Semi-Chemical	Tons (Air Dry)	Million	0.8	1.6	2.6	3.9	5.2										
Dissolving and Other Nonpaper Pulp	Tons (Air Dry)	Million	0.8	1.2	1.4	1.5	1.8										
Screenings, etc.	Tons (Air Dry)	Million	0.1	0.2	0.2	0.2	0.2										
Paper and Paperboard	Tons (Air Dry)	Million	29.0	37.4	42.7	47.9	53.5										
Paper	Tons (Air Dry)	Million	16.9	20.8	23.3	25.8	28.6										
Fine	Tons (Air Dry)	Million	1.3	1.6	1.8	2.0	2.3										
Coarse	Tons (Air Dry)	Million	3.1	3.8	4.2	4.6	5.0										
Newsprint	Tons (Air Dry)	Million	6.0	6.7	7.3	7.9	8.6										
Book and Other Printing	Tons (Air Dry)	Million	3.4	4.2	4.8	5.4	6.0										
Sanitary, Tissue, and Other	Tons (Air Dry)	Million	1.9	2.7	3.1	3.5	4.0										
Building Paper	Tons (Air Dry)	Million	1.3	1.8	2.1	2.4	2.7										
Paperboard	Tons (Air Dry)	Million	12.1	16.6	19.4	22.1	24.9										
Containerboard	Tons (Air Dry)	Million	5.6	7.4	8.5	9.6	10.7										
Boxboard and Other Paperboard	Tons (Air Dry)	Million	5.2	7.1	8.3	9.4	10.6										
Building Board	Tons (Air Dry)	Million	1.3	2.1	2.6	3.1	3.6										
Shingles and Shakes	Squares	Million	3.0	2.3	2.2	2.1	2.0	0.2	0.05	0.2	0.04	0.2	0.03	0.2	0.03	0.2	0.03
Cooperage	Board Ft., Lumber Equiv.	Million	504	511	490	452	390	0.5	0.07	0.5	0.08	0.5	0.07	0.5	0.07	0.4	0.06
Piling	Cubic Feet	Million	28	21	22	23	23	0.2	0.03	0.1	0.02	0.1	0.02	0.1	0.03	0.1	0.03
Poles	Cubic Feet	Million	103	110	112	121	128	0.6	0.11	0.6	0.12	0.6	0.12	0.7	0.13	0.7	0.14
Fuelwood[3]	Cords	Million	50	34	28	26	26	2.9	1.31	1.5	0.77	1.0	0.53	0.6	0.38	0.6	0.37
Wood for Distillation and Charcoal	Cords	Thousand	500	525	550	575	600	[2]	0.04	[2]	0.04	[2]	0.04	[2]	0.04	[2]	0.04
Miscellaneous	Cubic Feet	Million	250	250	250	250	250	0.4	0.25	0.4	0.25	0.4	0.25	0.4	0.25	0.4	0.25
Mine Timber (Not Sawn)	Cubic Feet	Million	100	100	100	100	100	0.2	0.10	0.2	0.10	0.2	0.10	0.2	0.10	0.2	0.10
Railroad Ties (Hewn)	Pieces	Million	15.8	15.2	14.6	14.2	13.7	0.6	0.10	0.6	0.10	0.6	0.10	0.5	0.09	0.5	0.09
Totals								49.1	10.11	49.4	10.34	49.8	10.66	50.1	11.06	50.8	11.54

[1]International ¼" Log Scale. [2]Less than 0.05. [3]Log and bolt requirements from living commercial timber only.

TECHNICAL SESSION I—Thur., May 6, 1954, 8:30 A. M.

Subject: Packaging

Chairman: E. R. Stivers

Recorder: James W. Goff

Recurrent Damage in Furniture Shipments

R. E. L. HARMON

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Much of furniture damage is recurrent and because of this is within means of control for prevention. While manhandling is a contributing factor to damage it is not the major cause as frequently attributed. Proper analysis of damage experienced together with examination of characteristics of articles and application of inner packing invariably provides the opportunity for corrective action at the source of manufacture and packing.

Introduction

CLAIM PAYMENTS FOR LOSS and damage to furniture in transit totaled $6,730,153 in 1953, as compared with $7,161,866 in 1952, a decrease of $431,713 or 6 percent.

I would like to dwell on this damage for a while, particularly as my major assignment as Furniture Specialist is prevention activity. One amazing fact regarding furniture damage is almost unbelievable, that is, rarely do you contact a shipper that has experienced trouble. Their statements are generally about as follows: "Our claims are negligible", "Practically nil" or "Less than ½ of 1 percent." These statements are made in all sincerity, but unfortunately claims are seldom filed by the shipper. Their knowledge of damage is generally based on demand for replacement parts and request for original bills of lading. Let us break this down as to actuality. Many types of damage would not require a replacement part nor would it reveal the articles rejected to the carrier for salvage. It is also true some consignees request the shipper to furnish original bills of lading but as a rule indemnity bonds are provided by them in lieu thereof in support of claims. Therefore, most claims are presented without knowledge of the shipper. In my experience, some shippers sincerely believe their customers would always inform them of excessive damage. A few do, of course, but most retailers in the prevailing buyers' market will purchase from another source rather than bother with transmittal of this information. I have dwelt considerably on this phase as I sincerely believe therein lies the possibility of prevention of recurrent damage—knowledge of its existence followed by corrective action.

The articles most often involved in recurrent damage are related to volume of the articles produced and shipped, case goods, tables and chairs heading this list with no one article being immune to damage. More than 90 percent of furniture damage is allocated to unlocated causes or concealed in nature. Determination of cause is most important for prevention to function. Ideal, of course, would be the ability to conduct a post mortem on each damage. With few exceptions, however, carload traffic is neither loaded nor unloaded by the railroads, and therefore, that responsibility rests with shippers and receivers. Because so relatively few shipments are inspected by the railroad before unloading, if the consignee fails to report the cause accurately, avoidable damage may be repeated over and over again. Likewise most articles involved in a concealed damage are unpacked prior to inspection by the railroad representative. Consequently, our damage is qualified as to nature and extent but invariably not as to cause. Our education of damage inspectors is progressing to an extent whereby they are originating much information of preventive value regarding extensive or repeater damage.

We all know an article properly and adequately packaged at the source has been started a long way toward safe delivery. Packaging specifications of the freight classification are minimum requirements with the majority of individual packages providing alternative methods of packaging. Many manufacturers exceed these requirements in providing additional inner packing to further insure safe delivery of their products. Packaging compliance and adherence to basic packaging principles have a major bearing on performance. Equally important is active supervision of packing forces and proper handling of articles from production to packing room.

It should be borne in mind the following causes of damage are not always positive, that is, all our damage cannot be charged to these reasons, but prevention has been accomplished frequently enough on these analyses for it to warrant your consideration.

Crated Furniture

Crated articles in Pkg. 5-F must conform to construction assembly, lumber dimension, specified clearances, and suspension. Recurrent types of damage to articles in this package generally consist of chafing of unholstery, finish abrasion or breakage of parts. Invariably this is due to inadequate blocking, bracing or suspension, allowing the article to move within the container.

Frequently, suspension members are placed lengthwise when crosswise placement would provide more substantial support for the article. Further, end nailing into suspension members is not good practice.

Damage has also been experienced with crated articles that are suspended with heavy unsupported weight causing splitting or breaking of the hanging portion at points of attachment to top. Solution: Subsupport or additional suspension.

Recurrent Types of Damage to Case Goods Packaged in Pressure Pack Method

Top Corners and Edges:

Damage: Bruising, splitting or breakage of these parts.

Cause: Inadequate or improper protection. Blanket materials of insufficient size to fully protect finished surfaces, selvedge edge of some types in some

ABOUT THE AUTHOR: HARMON, R. E. L. Speaker, Session I, Packaging, "Recurrent Types of Damage in Furniture Shipments" . . . Employed by the Association of American Railroads, Chicago, Illinois.

instance affording the only protection for these vulnerable portions.

Correction: Application of blanketing materials to obtain double thickness around perimeter of top through overlapping of body and top blankets. Certain styles with overhanging tops or with extremely square edges or corners required use of double faced corrugated fiberboard corner forms.

Legs or Flush Bases:

Damage: Splitting, chipping or breaking.

Causes: Improper positioning of wooden base frame members or too narrow dimension of frame cross pieces affording inadequate mounting. Splitting of legs or bases due to attachment to wooden frame.

Correction: Proper assembly and dimension of wooden base frame according to style of case. It has been our experience that legs or bases of case goods resting or floating on wooden base frame is much more desirable since shocks to base of container cannot be transmitted directly to article at point of attachment.

Sliding Glass Doors:

Damage: Chippage or breakage of glass positioned in running tracks, splitting of case end panels.

Cause: Existing track tolerance too great creating excessive movement in transit and jumping out of track; insecure blocking developing lengthwise play; impacts in transit against end panels splitting them at dowel attachment.

Correction: Best method is to wrap glass doors in fiberboard wrapper and position against back of case.

Hinge Doors:

Damage: Splitting of hinge rail, bending or loosening of hinges.

Cause: Inadequate securement of doors.

Correction: Friction type catches require proper alinement to hold doors. Bullet type catches generally provide positive positioning. Doors fitted with locks should be fastened. Our experience with magnetic type catches will have to be extended.

Finish Abrasion and Press Marking:

Damage: Excessive rubbing or marking of finish at various points.

Cause: Insufficient blanket coverage, article packaged with finish still warm from buffing operation.

Correction: Proper application of blankets or selection of material compatible with type of finish.

Drawers:

Damage: Divider partition or end panels broken or split. Finish abrasion of post.

Cause: Partition or end panels have been damaged by placement within the drawers of loose bundles of detached legs or hardware. Unsecured drawers with faces in contact with posts, vibration causing abrasion of finish.

Correction: Securement of bundles of parts within drawers to eliminate sliding impacts against partitions or end panels. Fastening of drawers in position to minimize vibration, particularly desirable when drawers are of recessed type or when faces of drawers are flush with each other.

Racking of Case Frame:

Damage: Loosening of case frame members especially at points of dowel attachment or glued blocks. Also splitting or breaking of various structural members.

Cause: Insufficient application of adhesive. Articles with excessive base span without packaging reinforcement.

Correction: Proper application of adhesive and reinforcement of base span either with artificial legs under structural uprights in center or placement of blocking of sufficient thickness near center to compensate the blocking or legs at end panels.

Mirrors:

Damage: Chippage or breakage.

Cause: Pressure exerted by fastening of clips or rosettes, inadequate forms failing to provide positive positioning and definite clearance.

Correction: Removal of clips or rosettes, positive maintenance of position and clearance with adequate forms.

Tables, Wooden, Set Up-Novelty Pieces

The extreme variety of styles and designs of this type of furniture presents many problems in that most of the packages authorized provide alternative methods of inner packing. Actually the choice of packing method by the manufacturer is based on knowledge of style and construction involved, his experience dictating those articles with styles of such nature that automatically require suspension.

Legs and Stretchers:

Damage: Breaking or splitting.

Cause: Legs mounted on improper wooden frame or suspension on inadequate forms.

Correction: Frame assembly insuring adequate positioning of legs, suspension forms of such design to bear weight and maintain necessary clearance.

Tops and Corners:

Damage: Bruising, denting, chippage, splitting and breakage.

Cause: Poor assembly of clearance forms or selection of inadequate material for characteristics of design.

Correction: Adequate forms or material to maintain proper clearances and positioning of article.

General Damage—Tables, Wooden, Set Up—Novelty Pieces

Damage has been experienced with certain styles of tables packaged in a suspension manner, either metal-strapped method under top or suspended on structural frame in which suspended weight is hanging like a pendulum, causing or splitting of these portions at point of attachment to top. Correction accomplished through provision of additional support or sub-suspension.

Wooden Chairs and Davenports

There are many types of packages authorized for these articles with a wide variance in packing specifications and numerous alternative methods depending on extent of upholstery, legs with or without stretchers, overstuffed and period styles and those of conventional design.

Each style has its particular characteristics with the package performance closely related to the packing method employed; therefore it is impractical at this time to cover other than damage in general.

Breakage of legs and chafing of upholstery are recurrent in nearly all packing methods and involve most styles of chairs and davenports. Cause frequently has been improper application of packing pads over vulnerable upholstered or finished portions, especially top of back rests and arm rests. Legs require careful consideration of style and construction to obtain the most effective method of protection.

Other Articles

Many of the other articles of furniture possess characteristics similar to those previously discussed and encounter damage of a like nature. Actually, packaging of furniture is relatively simple, most articles requiring a container, interior packing providing clearances or application of pad or blanket material, and base or leg protection. Package performance is dependent on analysis of construction and design of furniture to determine if article can carry the container or the container carry the article or if combinations of these two methods are required.

To emphasize again, much of furniture damage is recurrent and thereby within means of control for prevention through, first, knowledge of its existence and, second, thorough analysis as to cause followed by corrective action. Safe delivery of articles shipped pays dividends to us all.

Discussion

J. Howard Smith (General Electric): Vibration & Shock Tests—questions as to just how severe these tests should be and whether or not there is collected data from which one could calculate shock test severity.

Mr. Harmon: There is no such data available and it is felt that tests should be of such degree as to duplicate damage shown in field.

S. E. Strand (Brunswick–Balke–Collender): Is there a tabulation of types of recurrent damage in different types of furniture?

Mr. Harmon: No specific damage tabulation as yet. A new report form is being developed to furnish this information. So far adopted by fifteen railroads. Majority of damage is related to volume of article shipped.

J. A. Beauvis (Turner Manufacturing): Is the greater percentage of damage due to violation of package requirements or is the damage due to improper application?

Mr. Harmon: The majority of the cases are not outright violations but only misapplications of material in packages which comply.

Ed. Nagelkirk (Zeeland Furniture Company): Is damage due to handling or is packaging not meeting requirements? Do truck drivers and other handlers observe the direction arrows, etc. on the package?

Mr. Harmon: Handling is a contributing factor—the lack of supervision in the packaging operation is also a factor.

Earl Stivers (Package Research Laboratory): One Survey showed that most rough treatment occurred during handling, especially during loading and unloading. This was equally true of air, truck or rail shipments to furniture covering all phases that are within their means of control.

Mr. Strand: Surveys show that more damage reports come from some sections of the country than others. What is being done nationally.

Mr. Harmon: A special committee of the carriers has been set up to study prevention of damage to furniture covering all phases that are within their means of control.

J. Howard Smith: I have found that information that might be of value to persons interested and concerned with tests for packaging is contained in the following thesis:

Olyyar, E. G. *Survey Analysis and Classification of Hazards to Packages in the Distribution Cycle.* 1951 Masters Thesis on file at Library, College of Forestry, State University of New York, Syracuse 10, N. Y.

The Requirements For Good Furniture Packaging

JACK L. WARE

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This paper attempts to correlate the five basic principles of package design and development with the carrier regulations for shipping furniture. Other important considerations such as knowledge of construction and design of the merchandise, familiarity of the methods of distribution and the expected hazards they entail. Proper supervision of packaging operations, and the customers' point of view are discussed.

Why Packaging Is Important

WHEN ONE SPEAKS of the furniture industry, depending on his point of view, he might be thinking of one of the many divisions of the whole which might well be classified as a separate industry. Such divisions include upholstered furniture, case goods, occasional furniture, metal furniture, office furniture, school and institutional furniture, only to mention a few.

In spite of the fact that the industry is composed to a great extent of relatively small producing units, when annual production is all added up furniture sales rank second to automobiles among consumers durable goods.

When one looks at his own line he is apt to raise the question of the necessity of all this complicated packaging and the expense it entails. He looks on his merchandise as being well built, sturdy, constructed for years of usefulness. His thinking is absolutely right as far as it goes, but he is only analyzing the end use of the product and not the hazards it may encounter from his production line, through its normal distribution channels. Here lies the crux of the requirements for good furniture packaging. An analysis should include the method of distribution and its hazards, the kind of transportation used, the warehousing and the handling methods used in the originating plant as well as that which may occur at intermediate states of distribution.

To point out what I mean, I shall illustrate as follows: A manufacturer of bedroom suites might well expect his product, say a chest of drawers, to stand the average moving around for dusting or the usual rearranging of furniture that most housewives seem to enjoy. On the other hand very few of us would think of placing that chest on a vibrating machine for 24 to 36 hours or have any idea as to what might happen to the glue joints in the case, or, if there were a little looseness in the package, what might happen to the fine polished finish on the case. The same questions might be asked as to what would have happened to the fabric on an upholstered chair under like conditions, yet this kind of vibration and the length of time which it occurs are normal transportation hazards.

It is interesting to speculate as to what might happen in an LCL or mixed car shipment when heavy articles and light weight articles are loaded adjacent to each other and the car in which they are loaded is switched at 4 miles per hour which is considered normal handling. Something might be crushed. Did you ever run your car into a parked car or a brick wall at 4 miles per hour? I believe you would have quite a tendency to keep going. These are the same kind of forces that take place during normal in-transit handling of furniture.

Many of you are no doubt interested

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in furniture packaging or you would not be attending this session. Those of you who are responsible for packaging and shipping are familiar with the so-called "F" packages described and specified in the Uniform Freight Classification for all furniture shipped by rail. There may be some of you, however, who are new in the packaging phase of your business that might not know the background of these "F" or furniture packages. They were the first specified in the Official Freight Classification in 1946 after a joint industry and railroad study of successful furniture packages extending over a period of several years. Since the initial publication of these packages the total number of approved packages has been greatly increased as the need has risen and new materials and methods have proved their value.

Some of you are quite likely raising the question that if the railroads tell us how we have to pack why be concerned with how they or our customers handle the merchandise if it meets the "F" package requirements. That is a good question, but we must go further than that. Usually there are several alternative packages for any given item to be shipped and here the knowledge of handling and distribution methods and the normal hazards will help determine the correct "F" package for your merchandise. One thing must be borne in mind, that is that the "F" packages are minimum requirements and many times, due to the nature or design or construction of the item itself, or the way it is to be distributed, it is desirable to go beyond these minimum standards to assure safe delivery to the ultimate customer.

Much progress has been made in the reduction of damage to furniture since the adoption of the "F" packages as is evidenced by the reports on damage claims paid as released by the Association of American Railroads, yet there is room for further improvement in reducing this terrific economic loss which amounted to $5,976,045 in the first eleven months of 1953, the latest figures available as this paper is being prepared. These figures are for the railroads alone and do not include truck and private shipments nor the cost and trouble of handling the claims.

I believe that while the furniture industry covers an extreme variation as to type, materials, and construction, that in the matter of packaging that it is quite closely related if properly analyzed. I shall attempt to correlate the requirements for good furniture packaging on this basis.

Before making this analysis, I must assume that there is thorough knowledge of the product or item to be packed as this is just as important as the knowledge of the packaging materials to be used and the method and hazards of distribution.

Basically the requirements for good furniture packaging are to provide adequate protection, to deliver the merchandise to its final destination in its original condition, and, do so at the most economic cost.

An analysis of the causes of damage and the types of damage resulting from these causes are a good clue as to the kind of protection needed. For example, if the furniture is to be shipped by carload or truckload, much handling is eliminated. Thus, the type of damage which results from mishaps of handling such as dropping, bumping by hand trucks, tumbling off a 4-wheel warehouse truck or other hazards of handling assorted merchandise at transfer warehouses or docks, would not be expected. On the other hand, damage caused by vibration or crushing either from stacking load or impact will be encountered either on LCL, LTL carload or truck load.

Five Basic Principles

I would apply to furniture "Five Basic Principles of Protective Packaging" which must be considered in the analysis, development and design of every package. Some authorities have broken these down into as many as fifteen principles but for our purpose I do not feel a finer division is necessary. I will give you these principles and touch briefly on each.

1. **Surface Protection:** This may be described as the principle of protection against abrasion, rubbing, marring, bruising, soilage, fading, wetting of the finished or upholstered surfaces of the product.

2. **Compression Resistance or Container Requirements:** This is the principle involving the strength of the container itself.

3. **Vibration and Impact Absorption:** This principle may be applied to a package itself or to cushioning within a container.

4. **Anchorage or Blocking:** This principle is considered when product itself will withstand shock.

5. **Maintenance of Form or Closure Insurance:** This principle involves the proper closure, nailing or fastening of the container itself.

In considering each of these principles or elements of good package design, they cannot be considered individually but must be considered collectively as each involves the other and a change in one often necessitates a change in the other.

To illustrate my point suppose we have a case piece to pack which has a very highly polished, easily marked finish, in which we might well decide to use a so-called clearance pack. Here we would have to depend on the strength of the container, thus our second principle must be very carefully considered and our fourth and fifth principles would come in for their due share of consideration.

Had the finish been of a better or tougher quality we might have chosen a pressure type package and here we would have considered the kind and type cushioning needed for our surface protection, then principles 2, 3, 4 and 5 would be considered in an entirely different light.

While the five principles I have outlined are applicable to any package design, in packing furniture we have to be guided by the "F" packages. We, therefore, must select the package number which best suits our own particular need. Strangely enough although the furniture packages were not set up with these five divisions of principle specifically in mind, they coincide very well.

I have attempted to cover the principles to consider in the design and selection of the proper package. In practice, however, there are other factors which must be analyzed, to wit; cost and availability of alternate materials, standardization of methods, their advantages and disadvantages and your customers' appraisal of your packing methods, a most important factor.

Importance of Human Element

In any discussion of the requirements for good packaging, the human element and its proper supervision cannot be overlooked. The best designed package is destined to failure if all materials are not properly applied and the package securely closed. An excelsior blanket or pad will provide excellent protection for a delicate fabric if it is securely positioned to the furniture but if it were glued to the container instead, or just thrown in the box the cover could be rubbed from vibration in transit.

An end table might be well suspended in a container to protect its delicate legs yet if the supporting form were not properly assembled it would not do the job intended for it.

A five piece diagonally-braced skid is specified for many of the "F" packages yet if only one nail is used instead of two at each corner and if one end of the diagonal split when nailed there would be no strength there.

Thus, proper training and supervision of the packing room personnel can be a very vital factor.

Pre-Packing

I mentioned previously your customers' appraisal of your packing methods. I did this for two reasons. First, because there is no better place or way

to find out how good or bad your package performance is. Secondly, because there is quite a strong movement by retailers of furniture to obtain what is called Pre-Packing. This so-called Pre-Packing is nothing more than packing good enough so that the merchant can deliver your package to his customer without the expense of opening up, inspecting and De-Luxing. They are also desirous of packages which can be opened quickly and readily in the customer's home with easy disposition of the packing materials. Some manufacturers are taking additional steps in this direction by using tear tapes on their containers similar to the cellophane tear tape on a package of cigarettes or chewing gum, to make the opening job easy. We will be hearing more about this program as time goes on.

I would issue a word of caution here. In your zest to please your customer, be sure you do not reduce your package efficiency just to provide this Pre-Pack or else the program may defeat itself.

Conclusions

In summing up, I would like to emphasize the following points: (1) Know your product. (2) Know your method of distribution and the hazards of shipping it entails. (3) Consider the five principles of package design and the selection of the proper "F" package for each item. (4) Carefully consider alternative materials within the selected package and choose the one which best suits your product. (5) If from your knowledge of your product and its design you believe extra protection is needed beyond the minimum requirements, provide that protection. (6) Consult with your customers on the results of your efforts. (7) Carefully train and provide good packing room supervision. (8) Never forget your packaging is your public relations representative. It presents your merchandise to your public, your customer. It can be presented as fine, clean merchandise or as damaged goods of little use to anyone but the repair man.

Discussion

J. P. Foley (Weyerhaeuser Timber Co.): Is most excelsior used in the form of blankets and individual pads or is bulk fiber more widely used?

Mr. Ware: Most are in blanket form, but both are used. On certain upholstery furniture which can be packed in package 27–F, blankets are used.

S. E. Strand (Brunswick–Balke–Collender): What should packages cost? Why aren't costs for furniture analyzed as other commodities have been?

Mr. Ware: This is hard to determine for furniture because of the wide variation in article. Some relatively inexpensive article have fragile projections or fragile parts which require additional interior packaging which makes the relative cost of protection higher than a higher price piece which is of very sturdy construction, requiring the minimum of interior protection, therefore no average percentage could be wisely chosen.

Question—Why could not an average cost be determined for wood chairs?

Mr. Ware: For the reasons given to Mr. Strand's question.

Mr. Centilla (Baker Furniture Co.): Are there any steps being taken between carrier and carton manufacturers to develop adequate cartons?

Mr. Ware: This is being done by some companies as a matter of policy. Many areas, particularly those which have only a small amount of furniture manufacturing companies, have new representatives who have yet had little experience with the "F" packages and in some cases the companies themselves have had little experience with the "F" packages and are therefore unable to render the best service possible.

Earl Stivers (Packaging Research Laboratory): Is it not also true that the customer is always right? If he asks for a cheaper pack doesn't he usually get it?

Mr. Centilla: A package design at Baker Furniture Co. is an individual item. Some packages are sold to us which do not even meet the requirements.

Mr. Ware: There was a considerable amount of work done between railroads and suppliers during the early stages of package development. Unless the same co-operative spirit continues, there is apt to be a breakdown in package designs, either from lack of experience on the part of the shipper or in some cases demands of the user for lower cost packages, which may or may not comply with all the regulations. If there is doubt as to compliance of the package, I believe the inspection agencies of the railroad should be consulted.

Testing Furniture Packs to Insure Good Delivery

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The methods of testing furniture packaged within the various levels of permissible types of shipping containers is discussed relative to simulating in the testing laboratory the hazards of storage, handling, and transportation. Physical characteristics of furniture construction as related to testing and damage incidence are also outlined.

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THIS PAPER COULD, without too much effort, be considered as one on the impossibility of testing furniture and like packs.

Some of the problems encountered are in part caused by the multiplicity of methods of packing, types of product and method of transportation.

The number of packs permitted by carrier regulations which carry an "F" identification was, when this paper was drafted, 67.

Combined with the "F" pack descriptions are paragraphs specifically indicated under item 19501 on blankets, pads, bags, or envelopes.

These numerous packs and combinations of packs are by no means simple set-up shipping containers.

When a test of a packed item is

being considered, the method of packing should be checked against existing regulations to determine whether it meets requirements of the carrier.

With that fact established, it is then possible to continue your investigation of the ability of the pack to withstand simulated handling and transportation hazards.

Product Construction a Factor

After the pack has been subjected to the various methods of testing, another variable enters the picture. It is the type and efficiency of construction of the item being tested. Among the more prevalent faults which are disclosed are inconsistent finish, inefficient bonding at joined areas and low quality of the materials of construction. The Laboratory's experience in past tests will enable it to differentiate between package and product responsibility for damage.

Each of them present a different problem in testing. A method of test which would disclose a fault on one type would not develop the facts in the same manner on a substitute material.

One example would be a furniture item in which two or more methods of interior packing details are permitted. If the suspended item pack were dropped on a bottom end edge you would seldom have leg breakage. However, if the same item were fixed to a frame base with the legs fastened to the frame a bottom edge end drop could cause damage to the legs if the materials of construction were of low quality or packing details were not functioning properly. By the same analogy a suspended pack would possibly develop a fact under compression whereas another type of pack would indicate nothing of value. Metal construction would show weld or joint failures. These opposite values exist in a great number of packs. An example of different results under tests would be a plastic cabinet containing a rather dense unit. Under normal handling where damage results a finished wood item would possibly scuff or abrade on the surface permitting refinishing in an acceptable manner. The plastic under the same conditions would in the majority of cases be beyond repair due to the below surface changes which could not be corrected. In wood, joints would part; plastic would fracture.

Suiting the Test to the Case

In the various "F" classifications the outer container can be anything from a regular slotted container as a wrap, to a form-fitting 200-pound test with no limitation. Again different test procedures are necessary to disclose packaging, product or structural weakness.

The method of test is frequently indicated by the method of closure used on the completed pack. Closure efficiency varies depending on the pack used.

The level of simulated rough handling that a packed item is subjected to is governed by one or more of the following: (1) Method of transportation; that is, less than carload, carload, and parcel post. (2) Method of handling and storage in the productive stage. (3) Nature of pack and product. (4) Past performance of packed product in actual storage, handling, and transportation.

The methods of testing at the disposal of the testing laboratory are all of the standard methods plus those often developed to establish a failure or fact as demonstrated in actual service. We currently use vibration, drop, drum (both 7- and 14-foot) compression and combined incline impact, and some not presently accepted, to develop and establish facts. We are often called upon to subject substitute materials of furniture construction to extreme atmospheric conditions to compare their quality to material now in use. The substitution has been quite active in the past year.

Sources of Failure Within Pack

The factors contributing to container or interior packaging detail failure are numerous.

Some that we have encountered in corrugated packs are low grade components of fabrication, such as insufficient adhesive on facing material, inadequate bonding, extreme pressure during single facer operation, poorly formed scores, or crushed corrugations. Sometimes the outer container is incompatable with interior packaging details. This usually occurs where outer container and interior packaging details are procured from different sources.

Again the quality of interior packaging may be lower than specified. Faults in other than corrugated packs such as wood, plywood, cleated corrugated, wirebound and others are inadequate and improperly placed fastenings. Again high moisture content in wood, improper dimensions, or inefficient application of cushioning material may be involved.

Transportation Variables

Transportation variables also influence test procedures. Our most difficult method of transportation is parcel post. To determine whether a pack has an adequate factor of safety for parcel post handling, it is subjected to at least 50 percent more rough handling. Shippers frequently find that when they change from any form of transportation to parcel post, the cost of additional packaging for the same factor of safety is as much as one third higher.

Any criticism of existing furniture packaging should be done with the following facts in mind: The majority of the presently approved packs were as a rule advocated by a manufacturer of furniture, or a supplier of boxes and crates or interior packaging material and they are not wholly the result of carrier proposals exclusively. The fact that a pack meets specifications is not evidence that it will perform satisfactorily in service.

To classify the type of furniture pack and their individual method of testing plus the reasons for so testing would require a great deal of time and effort which at this time would be considered prohibitive.

The laboratory in its testing, attempts to determine the ability of the packs to deliver economically, if the pack fails in that effort it assists in fixing the responsibility for its failure.

Handling Small Parts in Pallet Boxes

Inter- and Intra-Plant Shipping

ALAN IRWIN

Plant Manager, General Box Company, Detroit, Michigan

The bulk handling of small parts from the point of manufacture to point of consumption brings in to play modern mechanical handling techniques. The field of material handling has enjoyed an unparalleled evolution in the past decade.

At the very heart of this vast program must lie the bulk container or "pallet box." The choice of the proper container to do the particular job on hand is a delicate and interesting challenge to the person responsible for efficiency and economy in the container program.

SOME OF THE FOREGOING discussion today has related to the Packaging and Packing of automotive parts for domestic distribution. When these parts are distributed from their point of manufacture, they may end up in one of two different types of locations:

A. They can be shipped to an automobile assembly plant, in which case they are known as "Production Parts," or

B. They can end up in a zone warehouse from which point they will eventually move to the automobile dealer who takes care of your car, and mine, in our local agency, in which case they are known as "Service Parts".

In either case, however, we see that a vast movement takes place from the point of manufacture to the point where, as a production part, they become a part of an automobile, or, as a service part, they become part of an inventory in a zone warehouse or on a dealer's shelf.

Whatever their ultimate use, it is desirable that these parts move out "in bulk" rather than individually. In other words, we want to handle a large number of these small parts at one time, rather than separately. There is, then, a need for some sort of a consolidating container into which a large number of small parts can be placed for more efficient handling—a container that will "make big ones out of little ones," so to speak.

Pallet boxes perform this function. A pallet box is just a box on a pallet, to simplify it to its lowest common denominator. It is nothing more or less than a consolidated container combining the features of a bin or box, and integrated with a pallet to facilitate mechanical handling.

As a general statement, these pallet boxes are available manufactured of paper, steel, or wood depending upon the purpose to be served.

The choice of type of material used, and the choice of design employed by the packaging engineer, are dictated by the function that is expected of this pallet box: This function, or job to be done, may be one of three—storage, intra-plant movement, or shipping.

(1) If its function is principally one of storage, with materials being placed in and taken out of the container without much movement of the pallet box itself, we can justify a pretty high cost, high quality, very sturdy and durable container that approaches the nature of an investment, rather than a shipping expense. It becomes part of a warehouse in the same sense that a row of metal bins becomes part of a warehouse. With this storage type of pallet box, the weight and cost of the pallet box can be higher than with either of the other two functions.

(2) On the other hand, if it is intended to be used as a carrier of parts between various buildings in the same plant or even between plants in the same company, it can again have fairly rugged characteristics, as it remains within the captive system and the title is not changed during the life time of the container.

(3) If however, our pallet box is intended as a consolidation container, to carry a number of parts to a customer, and title actually is conveyed to the customer, then different characteristics of the pallet box receive the most emphasis. Here we are confronted with a purely *shipping* container.

This last application, that of shipping, certainly covers the largest volume of pallet boxes that are manufactured. Incidentally, it is the most interesting challenge to the packaging engineer because the balance of factors must be more delicate to achieve an efficient economical pack. It is this "shipping" category with which we are principally concerned today.

As a general statement, pallet boxes for customer shipment can be divided into two broad classifications:

A. Returnable for re-use, and
B. Expendable.

Obviously, if the container is intended for re-use, it is going to have to be of huskier specifications than one that is intended for one trip. The railroads are currently conducting some studies on the feasibility of making returnable metal containers part of the permanent dunnage of a railroad car. As a general statement, there has been in the industry a very broad trend away from use of returnable wooden containers as contrasted with immediately following the war when everybody was thinking in terms of re-usable containers. The principal reasons for this trend away from returnable, re-usable pallet boxes, are briefly as follows:

1. Time lag between date of shipment and date that pallet box contents have been consumed at the assembly line, and the box can be ready for re-

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turn shipment. In some cases, this time lag is several months, and the "float" becomes too heavy, the investment too great.

2. Responsibility for repair of floor boards on pallets, and for loss of component parts such as sides or ends.

3. The shipper may receive back at his plant, containers supplied by a competitive shipper. In many cases, the container he gets back, which has been supplied by his competitor is distinctly interior to his own, and may even fail while in his possession.

4. The complexity of accounting for the pallet boxes. In other words, the problem of the bookkeeping end of the job. If the shipper decides by mutual agreement with his customer that five round trips should be par for the course, he will bill his customer at 1/5th of the price of the container on each trip. He may shortly find that he is only receiving 3 round trips with his container before it is lost or broken up or returned to the wrong shipper. On the other hand, if his container performs six or seven trips, his customer insists upon an adjustment. There is a never ending wrangle as to who is breaking up the containers and who should repair them.

5. The simple physical job of determining the inventory of these pallet boxes, and whether this or that pallet box belongs to source "A" or Source "B". That sounds like a very simple problem, but I can assure you that this objection is the most serious one to overcome. Someone will surely rise up at this point and say "why not invoice the pallet box as a separate item on the invoice just as the petroleum industry does with their metal drums?" Well, an oil drum is a one piece container of fairly durable material. In contrast, a pallet box mat from my company may not fit the pallet supplied by a competitor, and in our customer's yard they are inter-changed. There is more to this whole problem that I have indicated here, but suffice to say, that it is a very real obstacle to the general program of re-useable containers.

6. The return freight charges are considerable. Though much pressure has been brought to bear for lower return rates on empty or KD pallet boxes, the freight bill for the homeward trip remains an obstacle to re-use.

And so, we have seen that the expendable one trip container accounts for the great bulk of pallet box business at the present time and under present conditions. Expendable pallet boxes today are for the most part either (A) all corrugated, mounted on expendable wooden or corrugated pallets, (B) nailed panel or stitched panel type made of resawn slatted construction, either lined or unlined with corrugated material, and held in position as a box by horizontal banding, or (C) light wirebound construction.

The principle factors which influence the choice of these materials, and the determination of the specifications to be used, are as follows:

1. The amount of weight to be handled in the box.

2. Is shipment to be via truck or car, pure or mixed? This has the most direct influence upon the dimensions of the pallet box.

3. Length of the haul. Obviously shipment across the country required a different answer from that posed by shipment across the city.

4. Are the parts pre-packaged as for example in chip-board boxes, or are they bare?

5. Are the parts place-packed or hopper-packed in a jumble fashion?

6. Is the part of a nature to invite pilferage as for example automobile radios or hub caps?

7. Value of contents. A pallet box with several hundred dollars worth of spark plugs or radios will justify a little more investment than one containing a handful of raw metal stampings.

8. Will the pallet box be handled by transporters requiring a standard 3⅝ clearance, or will it move entirely so it can be handled by fork lift trucks.

9. If it is going to be handled by car, will it be shipped in a permanent dunnage car with two or three false floors in addition to the floor of the car, or must each pallet box be able to support an additional two or three stacked on top of it.

10. Is there a possibility of storing these pallet boxes outdoors in damp or humid conditions?

11. Does the customer intend that the box arrive at its first destination in satisfactory shape to be trans-shipped again or possibly twice more?

These are some of the many questions that must be considered in the determination of what pallet box is to be used to handle any given shipping problem.

Discussion

E. F. Landt (Forest Products Laboratory): Have you experienced any application of pallet boxes for air freight?

Mr. Irwin: The problem of loading and unloading is too great.

Earl Stivers (Package Research Laboratory): Our Laboratory has done some work with military shipments along this line. A lot of small shipments can be consolidated thus reducing handling costs. The pallet boxes are even being returned for reuse from overseas.

Preservation and Packing of Automotive Vehicles and Components For Export Shipment

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What precautions are exercised by the automotive industry to deliver approximately ten percent of its national production to overseas customers without excessive losses? The author has made a substantial contribution to the development of the export packing industry through his long experience in this field with General Motors Overseas Operations, both here and abroad. In this article he describes a few of the phases of automotive export preservation and packing as it is currently practiced by the auto industry.

THE PRESERVING and packing of vehicles and components for export, as practiced by the automotive industry around the world may be broken down into four distinct and separate methods —each having little relation to the other, except that all are destined for export shipment. These four methods are described below. Because of the interest of the Forest Products Research Society in container materials, I will discuss only boxed shipments.

	Quantity per shipment
1. Unboxed vehicles	1 unit
2. Boxed vehicles	1 and 2 units
3. Boxed components of vehicles	12 or 24 units
4. Boxed, crated, bundled etc. service parts	Any quantity

Boxed Vehicles (1 and 2 Units)

Conventional preservation and packing of a passenger car may be accomplished as follows:

Passenger Preservation: a. Application of a protective coating over all exterior bright metal to prevent damage from salt air. Such a coating should be tough enough to serve its intended purpose, yet easily removed with available and inexpensive solvents. Paste type wax is commonly used for this purpose.

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b. Oil combustion chambers and cylinders of engine in a suitable manner with an acceptable compound to prevent corrosion. Manufacturers' opinions vary both as to material and method for this operation, but most agree that it is a necessary requirement. Quality motor oil will fill this need, however, there are other products which are more satisfactory and more economical.

c. Drain fuel and cooling system.

Passenger Preparation: Parts removed from vehicle should be packed securely within the trunk or fastened to the interior of the shipping container in such a way that they will not damage themselves or the vehicle.

a. To reduce the overall length, remove front and rear bumpers, also the muffler tail pipe if it extends beyond the body.

b. To reduce the volume, compress front and rear chassis springs and secure compression fixtures against loosening.

c. Remove wheel and tire assemblies from axle hubs.

d. If the vehicle is equipped with a friction clutch, it should be partially disengaged to prevent adhesion of friction parts (50 percent of the clutch pedal travel should be adequate). Excessive disengagement of clutch will weaken its pressure springs.

e. Close all windows to within ½ inch of top of opening for ventilation and exclusion of foreign matter.

f. Open fresh air vents via dash controls for ventilation.

Passenger Packing: a. Locate the vehicle within the bottom panel of the shipping container so as to provide proper clearances from the vehicle to the sides and ends of its container when they are added later. Opinions vary on the proper method of securing an assembled vehicle to its shipping container, but a widely accepted practice involves the use of four metal-stamping-type brackets bolted respectively to the four axle hubs. Each bracket rests on and is nailed to suitable wood blocking secured in the bottom of the container.

These four fastenings should be the only contact between the vehicle and its container, other than the X-frame member clearance mentioned below:

b. Interior dimensions of the shipping container when assembled should provide minimum clearances from the vehicle as follows:

	Inches
X-frame member of chassis to bottom sheathing	6
Brake drum or backing plate to bottom sheathing	1
Side of vehicle to bottom framing (side sill)	1½
Side of vehicle to side panel framing or sheathing	2
Front of vehicle to end panel framing or sheathing	2
Rear of vehicle to end panel framing or sheathing	2
Roof of vehicle to top panel framing	3 to 4

Most exporters of trucks completely assemble and road-test them before delivery to the shipping department for packing. In some instances, assembly line operations are made with a minimum of attaching stock (just enough bolts and nuts to hold the vehicle together) to reduce disassembly labor in the shipping room. In other circumstances, vehicles are only partially assembled and such items as cabs, fenders, hoods, radiator shells, grilles, bumpers, running boards etc. are delivered from the production department to the shipping department via conveyor or industrial truck.

Conventional preservation and packing of two truck chassis and cabs (which have been assembled and completely painted) may be accomplished as follows:

Truck Preservation: a. See Boxed Passenger preservation (a.)

b. See Boxed Passenger preservation (b.)

Truck Preparation: a. Remove from chassis frame all assembled items

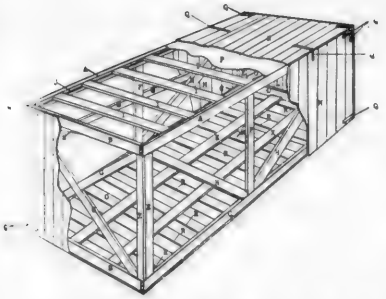

Figure 1.—A, top side sills; B, top end sills; C, bottom side sills; D, bottom end sills; E, corner posts; F, side struts; G, end diagonal braces; H, side diagonal braces; I, cross headers; J, cross header support; K, bottom battens; L, square-edge end sheathing; M, square-edge side sheathing; N, tongued-and-grooved top sheathing; O, square-edge bottom sheathing; P, waterproof paper; Q, corner irons; R, drainage cracks in bottom sheathing; S, side filler batten.

except motor and transmission, hydraulic brake lines and fuel line.

b. See Boxed Passenger preparation (d.)

Truck Packing: Two vehicles preserved and prepared as outlined above are packed in four separate packages, i.e.

Chassis case—contains two stripped chassis, all axles and sheet metal
Cab case—contains two cabs, all chassis springs and two radiators
Wheel and tire bundle — contains wheels and tires for 1 chassis
Wheel and tire bundle — contains wheels and tires for 1 chassis

Chassis Packing: The packing of two stripped chassis together with axles and sheet metal is made as compact as practicable but providing suitable clearances

between the lower engine and bottom of the container
between the lower transmission and bottom of the container
between the upper engine and top of the container
between the engines and crossmembers of frames
between the engines and axles

Effective fastening must be provided for all components of a two-unit chassis case to prevent movement which would result in damage. Customary practice follows securing of two chassis together with band iron or "U" bolts, then anchorage and support of this assembled mass within the bottom of the shipping container with wood blocking and band iron. Axles and sheet metal are next strapped upon and parallel with the upper surface of this grouped material. Tough paper, coroflex and corrugated paper products are used to protect sheet metal parts when packing.

This assemblage of material usually results in a package only slightly longer than the chassis frame with width and height approximately 48 inches each. It will be noted that the contents of this package are supported from and anchored to the bottom of the shipping container, without contact at other points, which simulates passenger car packing.

Cab Packing: Two assembled cabs are placed side by side, but facing in opposite directions when packing them on the bottom panel of their shipping container. Both cabs are individually supported from and secured to the container bottom panel. Support and anchorage is usually accomplished by bolting two wood members to the bottom of each cab in the same manner as a chassis frame supports and attaches to a cab. Then the ends of these wood members are supported by and secured to the side sills of the container bottom panel. Proper packing of two cabs in this manner would provide for minimum clearances as shown below:

1-inch clearance between cabs
2-inch clearance side of cab to end of container
2-inch clearance back of cab to side of container
No clearance front of cab to side of container
2½-inch clearance roof of cab to top of container

Chassis springs are usually packed within the cab case to reduce the weight of the chassis case and at such times are secured to the container bottom under the cabs. In such instances, if the chassis springs were left in the chassis case, the shipper would encounter a substantial freight penalty in the nature of a heavy lift charge (cases in excess of 6,720 lbs.). One radiator core, including its grille and sheet metal shell, can be conveniently packed within each cab, after securing the seat cushion to the back cushion.

Container Construction

Figures 1 and 2 illustrate the container construction generally in use both here and abroad, for the export shipment of passenger cars (1 unit) and trucks (1 and 2 units). This design is a very flexible one, easily adjusted in size and strength for a wide variety of vehicles or machinery. Also it lends itself to prefabrication in panel form, either at the point of use or in a box maker's plant adjoining the lumber source, which may be many miles distant.

A further advantage of this design is the ease with which it can be constructed as a reusable container. Such a container may be constructed in nailed panel form, then the panels joined by means of bolts and floating nuts.

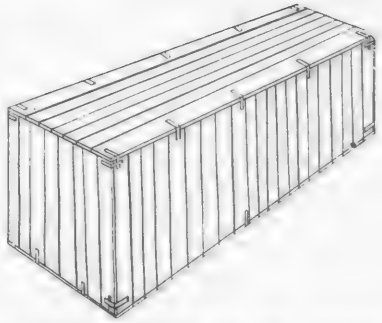

Figure 2.—Nailed wood case reinforcement—method of applying straps to corners and side edges of cases.

Lumber: Southern yellow pine lumber is used most extensively for export containers in the U. S. A., while Canadian spruce predominates in Canada.

Framing lumber consists of nominal 2 by 6, 2 by 4, 1 by 6 and 1 by 4 inch in No. 1 Common Grade.

Sheathing lumber consists of 11/16 inch thick resawn material surfaced one side and two edges in No. 2 Common Grade.

Tongue and grooved sheathing is generally used in construction of top panels with square edged sheathing elsewhere.

Nails: Assembly of lumber into panels is always made with cement-coated wire nails preferably with blunt points and sinker heads unless they can be clinched. Uncoated wire nails are acceptable only when they extend through the pieces of lumber being assembled and make a minimum clinch of ¼ inch, preferably ⅜ inch.

Waterproofing: The top panel of each container is lined with quality waterproof paper in a single sheet (not spliced). This sheet is fabricated between the framing members and the tongue and grooved sheathing of the top panel.

Ventilation: Export shipments encounter many variations in temperature which frequently result in condensation and resulting rust on metal surfaces, unless adequate ventilation is provided.

Shipper's preferences for ventilation methods vary widely. An efficient and economical means of ventilating painted vehicles when packed as outlined in this paper, may be provided for by omitting paper lining from side, end and bottom panels of the container which are constructed with square edge lumber.

Drainage: Shipments sometime encounter accidental damages in transit resulting in quantities of water entering the container. If drainage cracks ⅜ inch wide are arranged every 18 to 24 inches between bottom panel sheathing boards,

any water within the container will drain and prevent extensive water damage to merchandise.

Boxed Components of Vehicles (12 or 24 Units)

In the export automotive industry, we have a commonly used term known as CKD which represents Completely Knocked Down.

Automotive CKD, as shipped overseas, simulates the degree of assembly in which these parts pass from a manufacturing operation to a domestic assembly line. I will not attempt to itemize the myriad vehicle parts that are involved. Most manufacturers ship CKD components in sets of 12 or 24 because of proven nesting advantages.

Preservation: With CKD shipping, preservation becomes a much more extensive activity than with one and two unit packing of painted vehicles. Practically none of the CKD components are painted therefore, interior oiling of motors, transmissions, axles, steering gears must be provided either by the manufacturing or shipping department. All unpainted metal such as fenders, hoods, roofs, doors etc. must be protected against rusting. Two types of anti-rust protection are currently in use, namely vaporizing chemical inhibitors and rust inhibited oils.

Vaporizing chemical inhibitors are used in flake or powder form and blown by air gun as required. This material is also available on paper which can be used in various ways to prevent corrosion. Treated paper of this nature can be draped over materials, used as a case liner or a wrapper.

Oiling of parts against rusting may be accomplished by spraying, brushing or dipping and all three methods are employed.

Packing: Packing of unpainted CKD materials in containers requires blocking and bracing to prevent denting and/or breakage, but cushioning to prevent scratching is not nearly as necessary as with two unit packing of truck fenders and hoods, which are painted.

Many items such as horns, air filters, fuel pumps, lamps, mirrors, hardware etc. are received from suppliers packaged in corrugated cartons with paperboard separations to prevent one part damaging another. Such packaged material is packed as received within an export container.

Special precautions are exercised in the packaging and packing of glass and upholstery. Glass is packaged in wood crates or boxes which are blocked to the bottom panel of the trim case, then surrounded and covered with upholstery material. This case is of special construction to avoid condensation and exterior water damage.

Container construction for this type of shipping parallels that used for boxed vehicles. In addition, some shippers use a cleated panel type container which features a three-way corner. The cleated panel container seldom uses framing exceeding 15/16 by 6 inches and this feature permits clinched nail construction which is very desirable for concentrated loads.

Lumber: See Lumber under Boxed Vehicles, foregoing.

Nails: See Nails under Boxed Vehicles, foregoing.

Waterproofing: The top panel of each container is lined with super quality waterproof paper in a single sheet (not spliced). This sheet is fabricated between the framing members and the tongue-and-grooved sheathing of the top panel. In addition, side, end and bottom panels are lined with quality waterproof paper. Some shippers supplement this waterproofing with a waterproof umbrella sheet over the material within the container or an asphalt mastic and paper exterior coating or both.

Ventilation: Export shipments encounter many variations in temperature which frequently result in condensation and resulting rust on metal surfaces, unless adequate ventilation is provided.

Shipper's preferences for ventilation methods vary widely. However, most drill a specified number of holes of a given size in either side or end panels and cover with a baffle to deflect the elements. Some shippers drill a cluster of small holes at an angle in side or end panels and omit the baffle.

Drainage: Shipments sometimes encounter accidental damages in transit resulting in quantities of water entering the container. If drainage cracks 3/8 inch wide are arranged every 18 to 24 inches between bottom panel sheathing boards, any water within the container will drain and prevent extensive water damage to merchandise. To make this method effective in CKD containers, it is necessary to slit the waterproofing paper over each 3/8 inch crack.

Some shippers prefer to drill holes in the case bottom, while others prefer to omit drainage openings.

All of the three packing methods described above are intended for outdoor storage and handling via crane.

Boxed, Crated, Bundled, Etc. Service Parts—Any Quantity

Service parts referred to here are those repair parts which all automotive manufacturers ship to dealers to replace broken and worn parts during the life of a vehicle. Incidentally, the potential life expectancy of a motor vehicle overseas is much greater than in the U. S. A. or Canada.

Most manufacturers package many service parts today for domestic sales appeal. These domestic packages are acceptable overseas, except in rare instances where in order to satisfy governing regulations, some of the printing has to be obliterated.

Packing: No two orders for service parts, even from the same dealer, are never identical, consequently, each order has to be considered for packing on its own merits.

Shipping departments of automotive manufacturers who receive orders of substantial volume for export develop standard sizes of containers, which suffice for a large portion of their business.

Previous to 1952, most export service parts orders were limited in weight from 400 to 700 pounds gross per container because carriers and consignees seldom had facilities to handle heavier shipments. Most service parts shipments move via covered truck or railway car from point of origin to a covered pier or warehouse at seaboard, thence via covered lighter or truck to the steamship. Since these facilities are now equipped with fork trucks, we have only to make sure that overseas facilities of a similar nature are available to our consignees before increasing gross weights to 2,000 pounds. Currently some of our service parts shipments are going forward in containers equipped with skids carrying 2,000 pounds gross.

Preservation: The preservation afforded export shipments of service parts duplicates that used domestically, except in rare instances.

Containers: A wide variety of containers is used for the shipping of service parts. These containers consist of many types, for example; cleated plywood boxes, style no. 2 and 4 nailed wood boxes, twist and loop closed wire-bound boxes, nailed wood crates, 50-gal. steel drums, 5-gal. steel drums and pails.

In addition to the export containers many items such as wheels, muffler tail pipes, exhaust pipes etc., which lend themselves to bundling are strapped together in multiples by the application of flat or round steel strapping.

Usually the quantity of export service parts being prepared for shipment by a manufacturer represents such a small portion of his total business that the export container is influenced by the domestic container.

Export consignees are not fussy about container design as long as it delivers their merchandise without loss or damage, and its cost is not out of proportion to the value of the material being shipped.

The Use of Plastic-Surfaced Composition Board in Home and School Furniture

DAVID McCALLA

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Composition boards, or "Hardboards" as they are more frequently termed, consisting of wood fibers and natural or synthetic resin binders have long been a proven and acceptable forest by-product which have found and expanded their own end-use markets. In recent years there has been a very considerable increase in production of such composition boards, variations in type of board and in techniques of manufacture. Concurrently there have developed new materials utilizing composition boards as a part thereof, the use of composition board as a core material with various types of surfaces is one phase of such utilization. This paper discusses the use of laminated decorative melamine plastic surfaces on a composition board core for furniture usage.

Market and Demand

THE DEVELOPMENT and marketing of melamine-plastic surfaced composition boards for use in furniture construction has occurred through the evolution of a natural consumer demand for improved working surfaces having greater resistance to normal wear and abuse. Melamine decorative plastic laminates proved their ability to meet this demand in commercial applications and went on to establish themselves in the kitchen counter and table field and into the mass market of small dinette tables. With the comparatively recent development of excellent printed wood grains and improvement of color tones, decorative plastic surfaces of this type have now made a sizable entry into living room and bedroom furniture.

The transition from kitchen to living room brought about a change in requirements of major importance i.e., the necessity of an edge treatment consistent with similar furniture in wood, which precluded use of the conventional metal molding or open plywood core edges. While high quality hardwood lumber core plywoods with plastic surfaces and "self-banded" or "five-sided" plastic on plywood tops were able to enter this new market, their comparatively high cost limited their use and kept them out of the volume market.

In the institutional field the requirements for plastic tops on such items as hotel and motel furniture, dormitory furniture, and school desks and tables stressed to an even greater degree the necessity of a suitable working surface and edge treatment capable of withstanding the greater abuse inherent to the application and available at a reasonable cost.

Advantages

In applications of this type the advantages of a suitable composition board as a core, surfaced with decorative plastic laminates include: (1) Finished surfaces and edges providing high resistance to damage and deterioration, (2) core edges capable of being worked and finished by regular furniture methods at no additional cost, (3) smooth, flat surfaces, free from grain "telegraph" and gluing irregularities, and (4) lower costs achieved through savings in materials and processes.

Choice of Composition Board

The choice of a particular type of composition board for use as a core material, or the establishment of a target specification for the development of such a board, may be governed by the end use of the finished product or the surfacing process.

Choice of Core as Defined by End Use: We have previously discussed the market requirements for a suitable edge capable of being shaped and finished by standard furniture methods. To this requirement must be added the additional furniture requirements of: (a) Good impact strength—both surface and edge, (b) high fiber-to-fiber bond strength, (c) good screw holding power (although eventual screw holding power is increased to a large extent by the plastic surface), (d) good dimensional stability, (e) moderate weight, and (f) light natural color.

Almost all of these requirements, with the exception of weight, indicate a desirable core density of 50 lb. per cubic foot minimum. Inasmuch as a lower density core does not meet any of the other requirements, we must accept weight as a necessary disadvantage.

Choice of Core as Defined by Process: The application of decorative plastic surfaces to a composition board core may be achieved by (a) gluing previously laminated plastic sheets to the core in a secondary gluing operation; (b) laminating the plastic surfaces directly to the core, sometimes referred to as the "one-shot" operation; and (c) laminating the plastic surface to the core during the actual pressing of the core.

While the last method would appear to offer the greatest potential cost savings and is definitely a physically possible process, it is extremely doubtful that it is economically feasible due to the high reject factors encountered where the plastic surfaces are decorative and not subject to further finishing or refinishing after the pressing operation.

To define the relative advantages of processes (a) and (b) it is necessary to consider the density of the composition board core to be used. In process (b) the core must be of sufficient density to withstand the heat and pressure of the direct lamination of the phenolic and melamine surface materials, whereas in process (a) the core need only withstand the very moderate secondary gluing pressures. However, the very low density cores do not meet the previously outlined market and end use requirements. Therefore, we need consider processes (a) and (b)

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only in the light of core densities in the range of approximately 50 to 75 lb. per cubic foot. In this range the direct laminating process (b) proves superior on the basis of: (1) Cost—Through fewer operations, lower material costs, less trim loss, and fewer rejects through less handling. (2) Surface smoothness—Freedom from gluing irregularities. 3. Dimensional stability—Achieved through the high-strength hot phenolic bond between surface and core and the complete balance of surface resins and fibers.

From the foregoing we have concluded that a comparatively high density composition board is most satisfactory for our purposes, even though weight in itself is disadvantageous. To date we have found that core densities in the range of 60 to 70 lb. per cubic foot are necessary to maintain the other properties required. This high weight factor is not as serious a disadvantage as is often assumed—in fact, it has proven to be an asset in some types of furniture at the retail sales level. Nevertheless, it definitely increases the basic cost to the consumer, and tends to limit design in certain applications. Therefore, it must be regarded as the major technical problem in this field. Development work now in process by several composition board producers—and potential producers—show promise of maintaining other desirable properties at densities in the 50- to 55-lb. range, a weight decrease which would offset 80 percent of present weight disadvantages.

As a result of both production and experimental evaluation of a large number of composition boards, it is our belief that for use as a core in a direct laminating operation the dry process boards are far superior to the wet process boards with particular reference to fiber-to-fiber bond strength between the original wet felts and to the tendency of the wet process boards to delaminate between these layers under flexural stress. Fiber bond strength and resistance to delamination also indicate the superiority of a particle type board over a fiber type board, although recent developments in fiber type boards show possibilities of superior qualities at lower densities than have been realized in particle type boards.

Factors Affecting Sales and Utilization

The Furniture Manufacturer: While a certain amount of information regarding fabricating techniques, tools, etc., must necessarily be supplied to a furniture manufacturer planning to use plastic surfaced composition board, by far the greatest problem is to train diplomatically his usually competent woodworking employees. The problem is similar to that encountered in the early use of aluminum by sheet steel fabricators. A man having had decades of experience producing wood components for fine furniture is not exactly receptive to a stranger telling him how to saw, shape, route, drill, etc. a material which from its appearance, he considers himself well qualified to handle. Scant heed is paid to written instructions, and verbal assistance is usually met with either stony indifference or a "run along, Junior" attitude. Fortunately, the ensuing rejects are so glaring as to cause a rapid change of heart and the battle is won before the losses become serious. The detail requirements for carbide cutting tools, cutting speeds, etc. are no problem to the furniture plant once their need is accepted. The two real problems are those of handling a prefinished plastic surface and the necessity of accurately predrilling for screw attachments and using the proper size and type of screw. The former problem is rapidly dissipating as market demand causes more and more manufacturers to offer plastic surfaced furniture. The latter problem is usually overcome by sad experience, as described above.

The Furniture Salesman: The man selling furniture to a retail store has, in general, proven to be a capable sales engineer, both willing and able to absorb sufficient knowledge of a new material to present it intelligently and sell it effectively. For the laminator and the furniture manufacturer it is only required that they supply him the proper information and sales tools in the form of literature and samples.

The man selling institutional furniture users, such as schools, hotels, etc., is in the fortunate position of being able to sell a product that he knows answers a critical problem of his customer, and with that advantage his performance has been phenomenal. Again, providing the proper information and sales tools are the only requirements.

The Furniture Retailer: The factor affecting sales at this level is salesmanship itself. With apologies to the minority of capable retail furniture salesmen, we believe that the majority have very little detailed knowledge, or desire to acquire that knowledge, of the products they attempt to sell. This is a serious factor in the entire furniture industry, and an even more serious factor to those utilizing new products —whether they be a new and superior method of furniture finishing, or a plastic-surfaced composition board as a table top. With the buying public in the mood of demanding more quality for their dollar, amenable as never before to new ideas, and ready to break with traditional concepts for the advantages of modern design, function and materials, we serve them at the retail level with expensive advertising denoting mythical "1/3 off" sales and little or no pertinent information regarding the merits of the product. A truly negative sales approach. This is a serious problem regardless of product or material, and a disheartening one to those who would offer a new product of superior qualities. I regret that in making this criticism I cannot offer a constructive suggestion.

Consumer Acceptance: *Household furniture:* The growth of consumer acceptance for decorative plastic surfaces in household furniture is a matter of record. The additional attributes of a composition core having hard, durable edges, extremely smooth, flat surfaces and high resistance to impact damage have done much to change acceptance to demand. It is reasonable to assume that customer satisfaction will insure long range growth of this demand.

School and institutional furniture: Furniture in this category is subjected to exceptional wear and abuse and to a degree of vandalism. The rapidity with which the finest hardwood desk top, having the most durable of lacquer finishes, can become hopelessly defaced by a child with no other weapons than a sharp pencil and a ball point pen is amazing to those not familiar with school problems. Most educators seem to agree that vandalism, or the desire to destroy, is not the major problem—but rather the problem is that same tendency to absent minded "doodling" which cause adults to deface telephone booths. The type of damage caused by this problem is primarily surface "trenching" where a pen or pencil picks up a soft grain area in a wood top and makes a slight indentation which then becomes the focal point for further "doodling" and in a relatively short time becomes a deep trench and very often worked into initials or designs.

The uniform hardness and smoothness of the plastic decorative surface completely overcomes this problem in the school field.

The second most serious type of damage to school desk tops is through impact damage to the edges or student damage where open plywood edges or the slight crevice between the plastic top and a metal or plastic molding invite the prying efforts of the student's pen, pencil or knife.

The plastic surfaced composition board offers the most acceptable cure for this problem due to the high impact strength of the core itself and the homogeneous, smooth, shaped edges providing no crevice or material variations to invite prying.

These factors are of prime importance in school furniture and are also an important factor in other types of institutional furniture. In both types of furniture, surface abrasion wear can be serious and here again the exceptionally flat, smooth plastic surface, free from grain show-through or gluing irregularities, provides the utmost protection against this type of wear as the abrasive effect is dispersed over the full contact area rather than being concentrated on the "mountain tops" of the "telegraphed" grain or glue line irregularities.

On any school or institutional table tops where food is served, there has always been a sanitary hazard. On table tops with metal or plastic molding around the edges, the crevice between the top and the molding can trap food particles which become contaminated. Again, the plastic surfaced composition board with its smooth shaped edges eliminates entirely this potential hazard.

On hotel and motel furniture, and on some restaurant furniture, it has long been considered necessary to make "self-banded" or "five-sided" plastic tops both to protect the plywood core and to obtain satisfactory appearance values. While the appearance values are undoubtedly enhanced by this process, although at a comparatively high cost, the protection against damage is of doubtful value in that the corner and edges of the plastic banding tend to be chipped in service and result in a very poor appearance as well as being practically impossible to repair. On this category of furniture the use of plastic surfaced composition board with shaped and finished edges provides highly acceptable appearance values, and greater resistance to damage. Where moderate damage is sustained, it can easily be repaired by a light sanding operation and retouching of the edge finish, thus providing longer useful life at a lower cost.

All of these factors have been of prime importance in the rapidly growing acceptance of, and demand for, school and institutional furniture for working surface components fabricated from plastic surfaced composition board.

Discussion

Paul Graham (Woodworking Consultant): Does material require carbide tipped cutting tools?

Mr. McCalla: Yes.

James Hamilton (Souhegan Mills, Wilton, N. H.): When forming laminates while bonding you need high density, but what is the trade reaction to this high density core? What is density required in your type product, in the core material?

Mr. McCalla: Density of the core we are using at present is approximately 64 lbs. per cubic foot. While we have encountered some sales resistance due to heavy weight of this product, it has been more than offset by the ability to shape and finish edges without necessity of other banding material. Screw holding power is also important and in general increases directly with density. Face impact strength of the plastic surface is also important and, dependent primarily on the impact strength of the core material which also increases with density.

George Marra (Washington State College) (for Mr. Verbestal—S. A. Verkor): Is it possible to avoid warping without back sheets in processes B and C?

Mr. McCalla: No.

Mr. Marra (for Mr. Verbestal): What is effect of particle size?

Mr. McCalla: Particle size will have effect in processes B and C. Particle size in one shot operation can affect surface appearance due to possible swelling or spring back of particle after pressing. Particle size also affects the integrity of the edges and in general large particle sizes produce a poor edge.

Mr. Marra (for Mr. Verbestal): What pressures are usual?

Mr. McCalla: In most laminating processes on melamine decorative laminates, pressures in the range of 1,000 p.s.i. are normal. Pressures as low as 200 p.s.i. are possible under very carefully controlled conditions but are not feasible in production volume. For one shot laminating operations, it is our belief that pressure range from 350 p.s.i. is optimum.

Mr. Marra: (for Mr. Verbestal): Do you have specifications set up and do you have boards that meet your requirements?

Mr. McCalla: Yes. There are several boards available which in general meet our requirements, but we believe there must be continuing efforts towards improving core materials for this purpose.

Mr. Hamilton: What would you consider an optimum density for composition board that is to be used as a core to which a 1/16 in. plastic laminate is to be applied? Please take into consideration all types of end uses where weight may become an economic factor.

Mr. McCalla: Where plastic laminate is applied by process A (gluing operation), the density of the core to which it is to be applied will be determined by the surface smoothness to avoid "telegraphing" and the screw holding power of the core. Overall strength of the sandwich and decision as to whether edge banding will be used will all determine optimum density for the core board. The lowest density compatible with the foregoing requirements being most desirable.

Mr. Jean Verbestel (S. A. Verkor): Is it possible to avoid warping in processes C and B without balancing the board with a back sheet?

Mr. McCalla: No.

Mr. Verbestel: Is it possible to have the same high quality of surface in process A and in processes B and C, considering the minute difference in density due to the size of particles (compressibility)?

Mr. McCalla: We believe quality in processes B and C to be superior to that achieved in process A with respect to surface smoothness inasmuch as there is no gluing irregularity or grain telegraphing; however, particle size and density of the core in processes B and C can contribute to possible "orange peel" surface appearance where particle size is too large and density is too low.

Mr. Verbestel: Does the writer have quantitative specifications to meet his requirements? Is there a board that meets these requirements? Is the specific weight on dry basis?

Mr. McCalla: We have quantitative specifications to meet our requirements. To date there is not to our knowledge a core board that meets our specifications; however, there are several boards which have proven to be satisfactory for todays market requirements and from our knowledge of current development work by various board manufacturers, it is our belief that the next two years will see vast improvement in these boards as well as new boards which will be produced. The density figures previously referred to are on the basis of approximately 4% maximum moisture content.

Effect of Particle Size and Shape on Strength and Dimensional Stability of Resin-Bonded Wood-Particle Panels

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Precisely cut wood particles in the form of flat flakes, thin strands, helical ribbons, and cubes were converted to resin bonded panels. The panels ranged from 0.5 to 1.05 specific gravity. They contained variously either 2, 4, or 8 percent phenolic resin and, in some cases, developed strength and dimensional stability comparable to plywood. Several particles derived from commercial materials are also included in this comparison.

Particle shape, resin content, and density effects are related to bending strength, thickness change after water soaking, and linear expansion during cyclic exposure to 30 percent and 90 percent relative humidity.

Panels made with 4 percent resin, of various surface texture and having excellent properties, are technically feasible when based upon particles of sound fiber structure.

Introduction

BETTER USE of wood byproducts from diverse timber operations is a constant goal of wood research. The addition of basic knowledge that will contribute directly or indirectly to this objective is an important function of the U. S. Forest Products Laboratory.

It was in this framework that research was inaugurated on dry-form processes that would transform wood waste into structural materials and low-cost molding compositions. Wastes in the form of logging residues and unused byproducts from sawmills and manufacturing amount to about 350,000 tons per day (14).[2] The widespread and ample supply of this low-cost material has spurred process development, but the factors of capital investment, resin cost, market development, and a sparsity of basic technical information constitute formidable barriers to the use of significant amounts of normally wasted wood.

The raw material and market economics in Europe encouraged the early development of several types of wood-particle panels. Kollman (9) provides a review of processes and machinery widely used in European factories. A discussion of chip-core processes and their application to U. S. practice is given by Sides and Colucci (12). Elmendorf reviewed those compositions of excelsior and inorganic binders such as Portland cement in reference (5). Their studies show that an extensive development in the technology of wood-waste usage had taken place in Europe; yet the underlying technical and economic requirements for success in United States markets were not comparable to those factors prevailing in Europe. Despite the need for products of both higher quality and low unit costs, the main emphasis of U. S. development has been upon moderate-strength core-stock materials. The literature on this topic is now fairly extensive (1), (2), (3), (4), (6), (7), (8), (10), (11), (13).

Panel materials derived from sawdust or hammer-milled or hogged chips do not yield high-performance structural products unless the density and resin content are relatively high. However, these products are satisfactory for many applications, and their use has been increasing. Most of the present waste-using installations are combined with an established operation rather than in the form of an independent industry.

An appraisal of both performance and cost limitations showed that sawdust-resin compositions gave little promise of making a substantial use of waste economically feasible. With the above background factors in mind, the basic problem could be stated: Panel properties must compare favorably with accepted wood-base materials, such as plywood and hardboard, yet the resin content must be low enough to maintain costs within competitive limits.

The structural element in a bonded aggregate composition is the particle, and the consolidated product's performance is mainly a reflection of particle characteristics. The correlation of particle geometry and its structural quality with panel properties was thus a logical path toward further progress. A fundamental research approach rather than empirical improvement of conventional processes was therefore established.

The principal purpose of this report is to describe a series of particle-shape

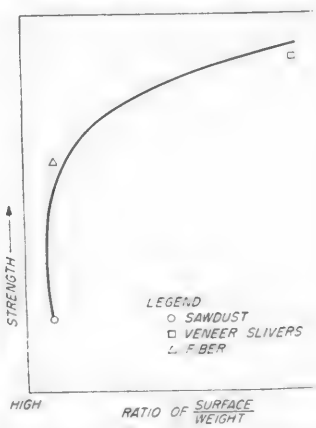

Figure 1.—Relation of resin-bonded particle-board strength to the particle's surface-to-weight ratio.

[1] This report is based on work conducted at the Forest Products Laboratory, Forest Sevice, U. S. Department of Agriculture, which is maintained at Madison, Wis., in cooperation with the University of Wisconsin. The present address of the author is Olin Industries, Inc., General Research Organization, East Alton, Ill.

[2] Underlined numbers in parentheses refer to Literature Cited at end of report.

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Figure 2.—Fibrous particles of commercial origin (above). *A*, coarse excelsior hammer-milled through a 0.75-inch-diameter hole, then passed over a 0.125-inch-mesh rotary screen; *B*, fine-grade excelsior processed as in *A*; and *C*, coarse fiber (produced by Wisconsin Wood Products Co.) processed as in *A*.

Figure 3.—*A* and *B* made with a 45° pitch cutterhead. They are 0.012 and 0.018 inch thick by 3-inch fiber length. *C* is an approximate cube, 0.070-inch side length, made by Wiley-mill reduction of thin cross-sectional wafers of Douglas-fir.

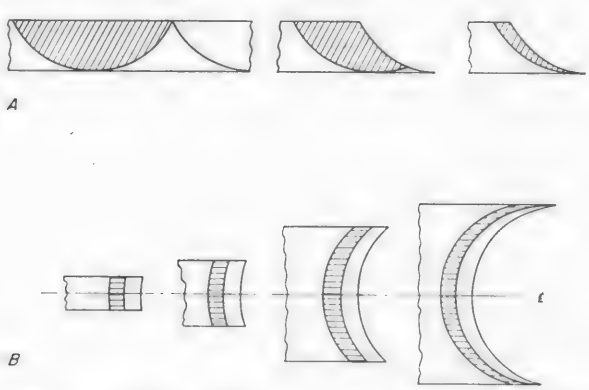


Figure 4.—Enlarged diagram (above) of chip sections generated by a rotary cutter. *A*, particle sections generated by tangential feed. The sections shown correspond to three rates of feed. *B*, particle sections generated by alinement of feed stock center plane, and cutter axis. These sections indicate the particle cross section when feed-stock thickness corresponds to varying fractions of the cutterhead diameter.

relationships to derived panel qualities. The essential principles involved can then be discerned and, with suitable interpretation, applied to a variety of specific practical problems.

Experimental Procedure

The primary objective of the experimental program was to establish a spectrum of data that would portray particle-shape influences upon panel performance behavior. A simple calculation concerning particle dimensional variables reveals that an enormous range of surface-to-weight ratios is involved; for example, from a 1/8-inch veneer to wood flour. Furthermore, the fibrous nature of wood compounds the problem; an equal surface-to-weight ratio in the form of fine sawdust and whole fibers would assuredly behave differently in panel form.

To clarify these issues a preliminary but crucial experiment was conducted. Two extremes of fibrous and nonfibrous particles in the shape of fine sawdust and whole-wood fiber were selected. A third extreme, particles of sound fiber structure but with a very low surface-to-weight ratio, was provided in the form of screen-fractionated hammer-milled veneer strips. The 1/16-inch veneer was cut into strips 1 inch long in fiber direction; thus milling breakage was mainly parallel to rather than across the fibers. The resultant blunt-ended sliverlike particles were screened to yield a fraction free of both excessive fines and thick splinters. These veneer-based particles were from 1/8 to 1 inch long

and cross sections varied from about 1/64 to 1/16 inch square.

These three particle extremes, sawdust, fiber, and slivers, were then treated with equal amounts of resin, converted to flat panels, and tested. The qualitative test results are shown in figure 1. This single experiment thus forecast the general area in which optimum quality would be found; fiber structure must be undamaged and the surface-to-weight ratio should tend toward that of veneer rather than that of individual fibers. Therefore the field of intensive research would be most fruitful when confined to particles complying with these general specifications.

Particle-Preparation Methods

The range of particle dimensions had to be chosen with reference to techniques available for particle generation. As is frequently the case, the practical, working program represents a compromise between the desirable and the possible.

The approaches to particle generation may be roughly classed as (1) random production followed by classification and (2) precise cutting that requires little if any subsequent classification. The latter method is preferable for research purposes since a particle of controlled, uniform dimensions is the sole product. The sliverlike shapes from veneer is an example of the random-fractionation method. A similar processing sequence was used to make test particles from commercial excelsior and a coarse, mechanically made fiber such as that produced by the Wisconsin Wood Products Company. These fibrous materials were first hammer-milled, then screened on a small inclined rotary classifier. Typical fibers obtained are shown in figure 2. The procedure for making the cubic particles presents a hybrid of the 2 methods; end grain wafers about 1/16 inch thick were sawed from a 2 by 4 and then reduced in a Wiley mill in which the knife clearance was set at about 1/16 inch. The ground product was passed through a 1/8-inch perforated basket (in the Wiley mill), then screened subsequently to eliminate fines. By judicious selection of a Douglas-fir 2 by 4 for uniform annual-ring spacing of about 15 per inch, the above technique provided a satisfactory yield of uniform cubelike particles, a sample of which is illustrated in figure 3, C.

Although the random-classification particle-preparation method is simple and direct, it was inadequate for a thorough study of particle geometry effects. A method based on precisely controlled cutting was needed. The initial attempt along this line utilized a metal planer. A plow-type cutting tool having a 2-inch cutting edge on the

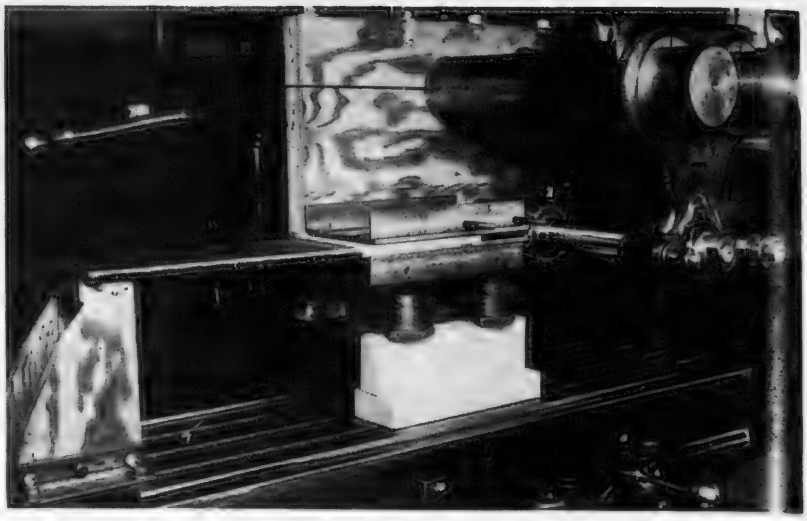


Figure 5.—Milling-machine adaptation used for experimental wood-particle generation. The near-side plywood vertical support panel has been removed here to illustrate the block portion in the feed channel. The temporary screw-jack supports below the feed slot were necessary because of absence of plywood panel. The ¼-inch pusher bar (projecting toward the right from the top of the triangular brackets bolted on the machine table) pivots at the left end to allow easy insertion of wood blocks in feed channel.

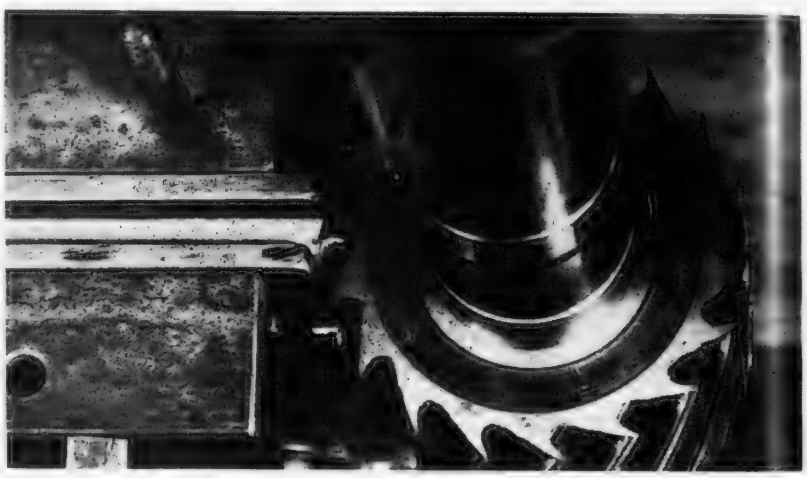


Figure 6.—Detail view of milling cutterhead cutting flake from feed stock. A thin phosphor bronze flap spring, attached to the inner surface of the upper channel plate, prevents the wood block from vibrating during its advancement into cutting circle.

sides of a diagonally oriented, square, tool-steel bit was used. By adjustment of wood-block size, cross-slotting pattern, and veneer laminating technique, both thin, flat flakes and helical strands could be made. This procedure was tedious, but it did yield particles whose dimensions were under precise control.

A more versatile and far more productive system was devised by modification of a standard milling machine. In the early trials a short plank section was clamped to the machine's reciprocating table, and tangential cuts were made as in milling a metal slab. When the grain direction is parallel to the cutter axis, uniform relatively undamaged chips are rapidly produced. However, by using the conventional tangential feeding arrangement, which is common practice in wood planers also, a chip of nonuniform cross section is generated. The cutting principle is sketched in figure 4, A. The usual chip form had a fragile trailing edge that was easily broken, while the wedge-shaped cross section caused distortion during drying.

The objective of a virtually uniform chip cross section was achieved by suspending a rigid, stationary feed table in front of the milling cutterhead. This setup permitted coincidence of the feedstock center plane and cutter axis so that the entire block was converted to flakes as it advanced into the cutting circle. The diagram in part B of figure 4 illustrates this principle.

The illustrations of figures 5, 6, and 7 show the essential mechanical feature of this milling-machine adaptation. By appropriate selection of cutterhead, spindle speed, and feed rate, the particle

Figure 7.—Rear view of milling machine setup. Feed-block sample (kiln-dried) and type of flake generated are on machine table. Tube line provides compressed-air jet to aid in discharge of chip from cutterhead.

thickness could be precisely controlled. It was found that flake sections below 0.005 inch thick were excessively damaged. This thickness dimension is on the order of 2 or 3 fiber diameters; thus it would be inevitable that an appreciable fraction of total fiber content would be subject to damage by the cutting edge when cross sections in this range are generated. The upper practical chip thickness, with this equipment, was about 0.050 inch. At this dimension the chip did not flex readily and frequently clogged the gullet region of the cutterhead. It was also noted that the particle surface texture tended to resemble the open and closed faces of a poorly cut thick veneer.

Since the chip-removal process described is a slicing action, veneer-cutting technology serves as a guide to minimizing fiber damage in this system. Reasonably good particles may be produced from the dry wood of some species, but the use of water-soaked or green material is perferable to retain maximum structural quality in the particle. In this work water-soaked Sitka spruce was used for making all the flat- and helix-shaped flakes.

A photograph of some cutters employed in particle generation studies is

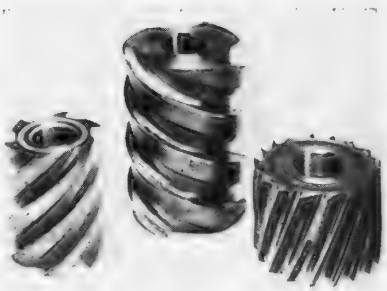


Figure 8.—Typical milling cutterheads used in making experimental particle shapes. The center cutter has only 3 cutting edges, which form 68° left-hand helixes. The left cutter has 6 cutting edges disposed as 45° right-hand spirals. The right-hand cutter, which was ground to provide an increased hook angle, has 18 teeth at about a 20° right-hand spiral.

presented in figure 8. The general form or configuration of the particle is governed by the cutter-edge geometry. The 45° and 68° helical cutters produced helix-shaped particles such as those shown in figure 3, A and B. The 20° cutter yielded flakes that were nearly flat, particularly if the cutting was from wet wood. Typical examples of the latter flakes are shown in figure 9.

A precise strand-making technique was developed as follows: Sliced Sitka

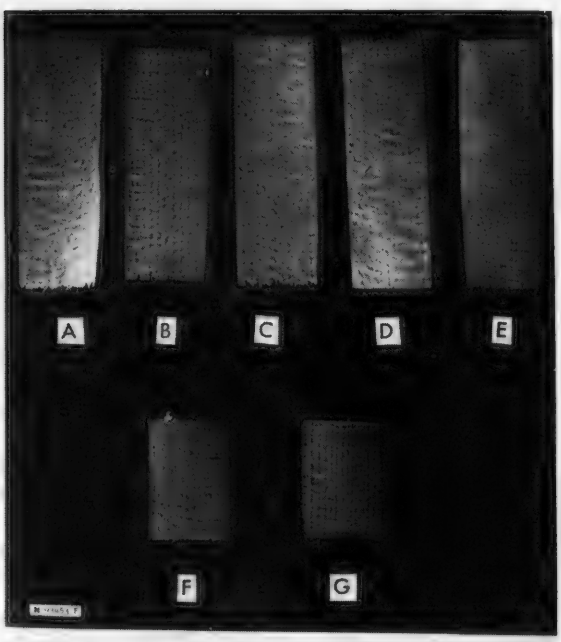


Figure 9.—Flakes cut from wet spruce. Those of upper group are about 3 inches long; of the lower group, about 1.50 inches. Thickness values are:

Inch	*Inch*
A—0.006	*E*—0.030
B—0.007	*F* —0.018
C—0.009	*G*—0.030
D—0.018	

Figure 10.—Illustration of method used to generate controlled-size strands. Blocks are parallel-laminated spruce veneer. Flakes below blocks are all 0.018 inch thick, from which the strands under the flakes are derived by dissolving the glue (hide glue) with hot water.

spruce veneer was conditioned at 90 percent relative humidity for several days, then parallel-laminated, with hide glue, into slabs about ½ inch thick. Following removal from the cold press, the laminated planks were crosscut into pieces whose length in the grain direction corresponded to the desired final strand length. These sections were then immediately reduced to flat flakes by using the milling cutter equipment described above. These flakes were then immersed in hot water; whereupon the glue holding the flakes together quickly dissolved and separated, relatively undamaged thin strands resulted. The cross section of the strands was determined by the initial veneer thickness, 0.042 inch in all cases, and in the other direction by the cutterhead-speed and feed-rate relationship. A constant cross section was used for all strands made in this program—the only dimensional variable was length in the grain direction. The 90 percent relative humidity conditioning facilitated particle cutting. An effort was made to use still higher moisture content, but the resultant glue bond was so weak that delamination occurred at the cutterhead with attendant extensive fiber damage. The final phases of this particle-generation scheme are outlined in figure 10. This procedure, though possessing excellent control features, may be aptly described as a laboratory curiosity.

The lack of fiber damage shown by a wide range of flake thicknesses is of technical significance in the appraisal of the rotary milling cutter method of particle manufacture. A brief, hypothetical example indicates the output potential of this mode of particle production. For the ensuing calculations it is assumed that rectangular slabs are continuously advanced into the cutter.

Notation terms:

- L = length of feed stock (inches) grain direction parallel to cutter axis
- T = thickness of feed stock (inches)
- t = chip thickness produced (inch)
- N = number of teeth on cutterhead
- R = cutterhead speed (revolutions per minute)
- F = feed rate of stock (inches per minute)
- V = volume of wood converted per hour (cubic feet)

Values assigned for purposes of illustration are as follows:

- L = 24, T = 1.0, t = 0.010, N = 12, R = 3,600
- F = to be computed
- V = to be computed

F, feed rate, is independent of length, L, and thickness of stock, T, but is governed by teeth on cutterhead, its speed, and desired flake thickness in accordance with the equation:

$$F = NRt \text{ or } = 12(3{,}600)(0.010) = 432 \text{ inches per minute.}$$

The theoretical volume consumed per hour is then computed from the relation:

$$V = \frac{FLT(60)}{1{,}728}$$

$$\text{or } V = \frac{432(24)\ (1)\ (60)}{1{,}728} = 360 \text{ cubic feet}$$

per hour and, by using a density value of 40 pounds per cubic foot (dry basis), the converted wood weight is: 360(40) = 14,400 pounds, or in the neighborhood of 7 tons per hour per machine.

Although a wide latitude is permissible for the feed, dimensional, and cutterhead variables, it is evident that capacities in the range of several tons per hour per machine are within the realm of engineering feasibilty.

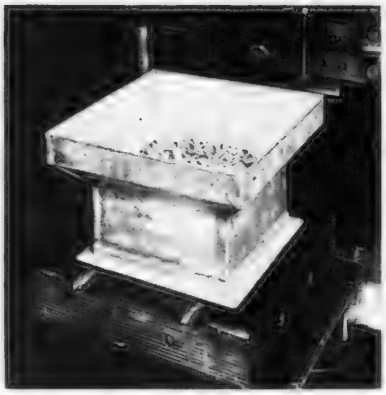


Figure 11.—Mold with loading hopper in place. This added side height is needed with the more voluminous particles.

Figure 12.—Particle charge under mold plunger ready for consolidation and a typical panel as it appears when first stripped from the mold.

Resin Application

Resin treatment levels could be based on two differing concepts, (1) resin weight relation to the particle's surface area, or (2) a weight fraction of the particle. The first basis has some theoretical justification, but its interpretation becomes meaningless in dealing with batches of random-dimension particles or those similar in dimension but of varied surface texture. For these reasons, and also from practical considerations, the resin content was based on the initial dry weight of wood particles.

Preliminary efforts to apply dry, pulverized resin on dry particles were unsuccessful. Distribution uniformity was poor, segregation of resin in the mold was evident, and dusting losses were indeterminate. Spray application of a water suspension of powdered phenolic resin proved to be satisfactory. A pulverized, water-insoluble resin was preferred because its use simplified treatment control problems. For instance, the uniformity of distribution on the particle could be quickly checked via microscopic examination, while resin penetration would be essentially constant regardless of the moisture content of the particle at the time of treatment. Resin concentration in the suspension was altered for the three levels of treatment in such a way that the total weight of suspension applied was the same for equal-weight lots of particles.

Estimation of the resin-spray losses was initially verified by including in the suspension a weighed amount of water-soluble dye that had a high, narrowly defined, spectral absorption. After spraying, a sample of treated particles was thoroughly water extracted, the extract's spectral transmission was measured, and, from the ratio of sample weight to that of the total batch of treated particles, the spray loss was determined. Retention level was not less than 90 percent, and in most cases it was probably nearly 100 percent.

A conventional pressure-type spray gun was used to apply the suspension. A 4- foot diameter, slow-turning drum mounted on a horizontal shaft was used to tumble the wood particles as they were sprayed. Microscopic examination of treated and untreated thin, flat flakes showed uniform resin coverage even at the 2 percent level. The moist, treated particles were dried at 50° C. in a forced-circulation oven, then conditioned to 10 percent moisture content prior to hot-pressing.

Panel Preparation

Conditioned particles in 250-gram batches were hand-distributed within a 4-inch-deep 10- by 10-inch mold. The mold, press arrangement, and a typical panel before and after pressing are shown in figures 11 and 12. Pressure

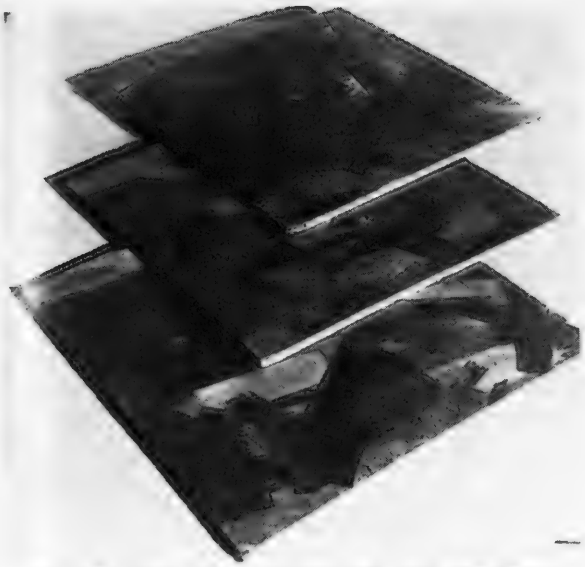


Figure 13.—Test panels (10 x 10 x 0.20 inch) from various thicknesses of Sitka spruce flakes 3 inches long.

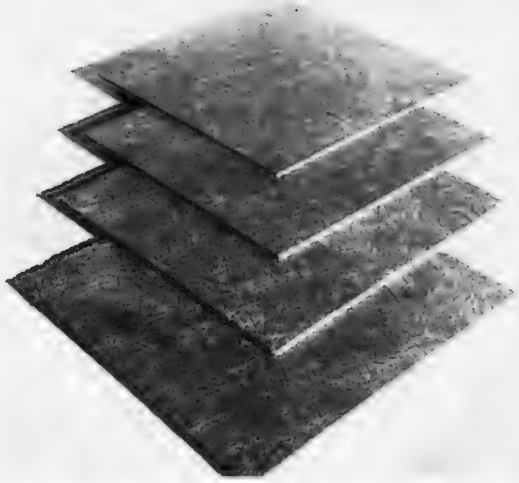


Figure 14.—Sitka spruce strand-based panels. Strand lengths from top down are 0.375 inch, 0.75 inch; 1.50 inches, and 3 inches.

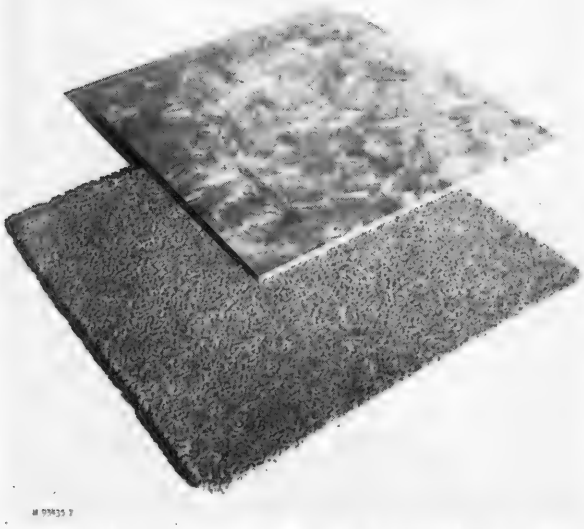


Figure 15.—Panels made from 3-inch-long helical flakes of Sitka spruce and small cubic particles of Douglas-fir.

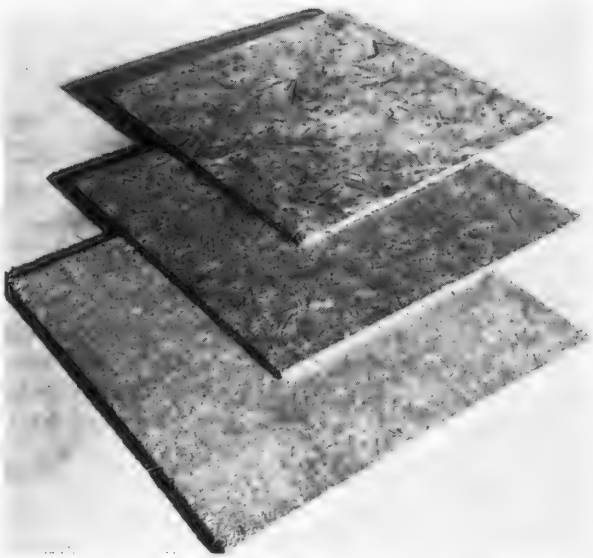
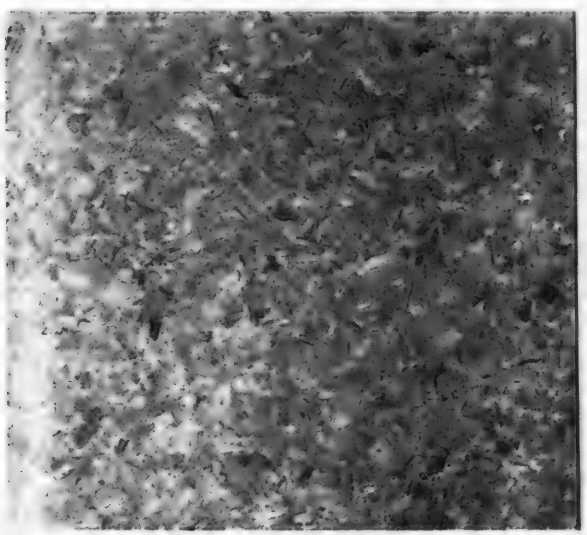


Figure 16.—Panels based upon commercially available fibers made from aspen.



gure 17.—Panel made from dry Douglas-fir planer shavings screened to pass over ⅛-inch mesh opening.

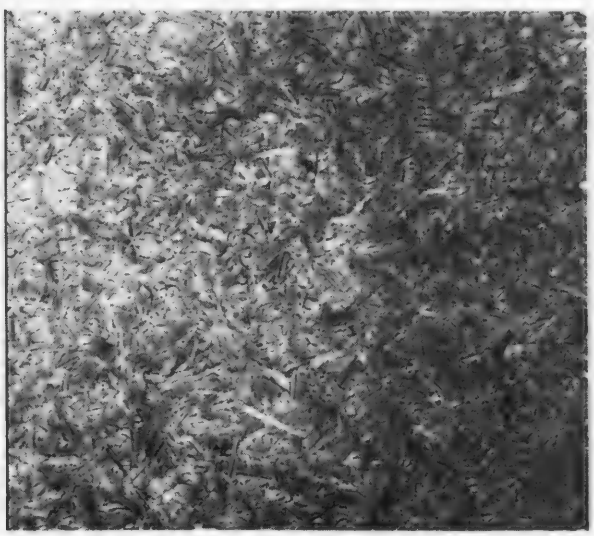


Figure 18.—Panel derived from green Douglas-fir planer waste, hammer-milled and screen-fractionated over ⅛-inch-mesh opening.

levels of 250, 500, and 1,000 pounds per square inch were used to produce panels of various densities. The molding cycle was done at 160° C. for 15 minutes, and all test panels were withdrawn hot from the mold. They were subsequently trimmed and racked for conditioning at 65 percent relative humidity for 14 days or longer. A representative sample display of the various test panels made is shown in figures 13 through 18.

The entire test series included the following particle shapes and species:

(a) *Flat flakes:* 1.5- and 3-inch lengths, specially cut from Sitka spruce.

(b) *Helical ribbons:* 3-inch fiber length, specially cut from Sitka spruce.

(c) *Straight, thin strands:* 0.4- to 3-inch length made by laminated-veneer and flake-generation technique from Sitka spruce.

(d) *Cubic:* made by Wiley milling and fractionation of thin, end-grain wafers of Douglas-fir.

(e) *Excelsior:* made from commercial grades of coarse and fine aspen material.

(f) *Fiber:* from mechanically made coarse-grade aspen supplied by the Wisconsin Wood Products Co.

(g) *Planer shavings:* mill waste from both dry and green Douglas-fir lumber. Supplied by Weyerhaeuser Timber Co., North Bend, Ore.

Testing Procedure

Measurements were made for the determination of (a) specific gravity, (b) modulus of rupture at 65 percent relative humidity, (c) modulus of rupture after two water-soaking, ovendrying cycles, (d) springback or change in thickness following two water-soaking, ovendrying cycles, and (e) linear expansion during cyclic exposure to 30 percent and 90 percent relative humidity.

Bending tests were in general accord with Tentative Method D-1037-52T of the American Society for Testing Materials. Specific gravity values were based on specimen weight and dimensions at time of test.

Linear-expansion measurements were made on panels conditioned to constant weight at 30 percent and then at 90 percent relative humidity. The expansion percentage reported is based on the difference between the initial dimension at 30 percent relative humidity and that at 90 percent relative humidity following 3 cycles of exposure.

Presentation and Discussion of Results

Approximately 350 tests panels were involved, from which more than 2,000 specimens were derived. Condensation of the results and their interpretation was therefore necessary.

Table 1.--Particle description

Particle class	Species	Symbol	Length	Width	Thickness	Average weight	Area ÷ weight
			Inches	Inches	Mils	Grams	Sq. cm. per gm.
Plywood	Sitka spruce	P	10	10	42	24.5	53
Flat flake	do.	3F6	2.9	.95	6	.100	360
Do.	do.	3F7	2.9	.95	7	.116	310
Do.	do.	3F9	2.9	.95	9	.143	250
Do.	do.	3F18	2.9	.95	18	.284	125
Do.	do.	3F30	2.9	.95	30	.502	71
Flat flake	do.	1.5F18	1.35	.95	18	.133	125
Do.	do.	1.5F30	1.35	.95	30	.234	71
Helix flake	do.	3H12	2.9	.45	12	.090	190
	do.	3H18	2.9	.40	18	.130	105
Straight strand	do.	.4S	.40	.042	18	.00155	400
	do.	.8S	.80	.042	18	.0031	400
Do.	do.	1.5S	1.50	.042	18	.0068	400
Do.	do.	3S	2.9	.042	18	.0136	400
Cube	Douglas-fir	K	.070	.070	70	.0027	71
Excelsior	Aspen		About	About	About		
Coarse	do.	XC[1]	1	.050	15	.0051	165
Fine	do.	XF[1]	.5	.025	15	.0012	220
Fiber	do.	WF[2]					750-2,[illegible]0

[1]Excelsior was commercial grade material, hammer-milled through 3/4-inch-diameter perforated basket, then passed over 1/8-inch-mesh rotary screen.

[2]Coarse grade of mechanical fiber supplied by Wisconsin Wood Products Company. Screened over 1/8-inch-mesh rotary screen.

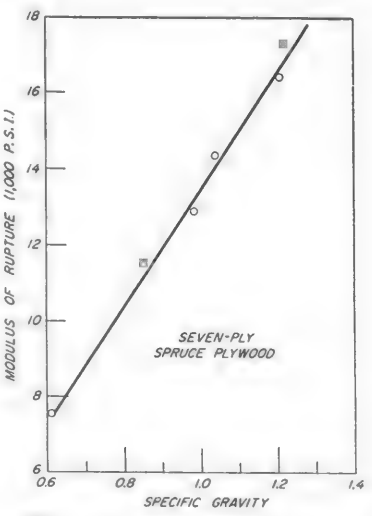


Figure 19.—Results of strength tests of seven-ply spruce plywood panel.

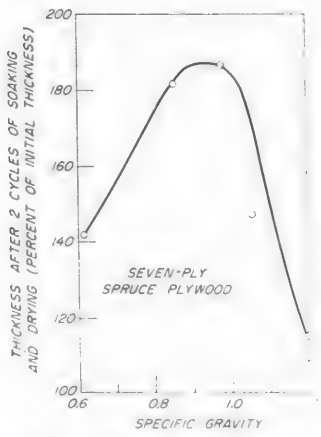

THICKNESS AFTER 2 CYCLES OF SOAKING AND DRYING (PERCENT OF INITIAL THICKNESS)
SEVEN-PLY
SPRUCE PLYWOOD
SPECIFIC GRAVITY

Figure 20.—Relation of thickness springback to density of seven-ply spruce panel after soaking.

Descriptive data on the principal particles are given in table 1. The particle abbreviations shown there are used in table 2, which summarizes the average values obtained for panel density, strength, and dimensional change under the two types of cyclic exposure employed. The data for panels 300 to 347 were extracted from a previous Forest Products Laboratory typewritten report of the suitability of Douglas-fir planer shavings for core-stock material. The planer shavings, which typify one form of waste commonly available, were included to broaden the basis of comparison.

A reference standard was considered to be essential in making comparative evaluations. In this work seven-ply (0.042-inch veneer) crossbanded Sitka spruce plywood served this function. Plywood panels were assembled at several pressures to bracket the anticipated specific gravity range of the particle-based boards. The strength-density correlation of the plywood control series is given in figure 19. Plywood

thickness springback was markedly affected by density and shows a pronounced maximum in figure 20. The improvement in stability beginning at 1.05 to 1.10 specific gravity is perhaps due to permanent fiber-cavity deformation similar to that obtained in making the material called "staypak." It is also possible that the higher densities simply increased resistance to diffusion so that water penetration during the immersion cycle was greatly retarded. In the appraisal of springback data, it should be realized that the extent of thickness recovery is affected by the density of the wood from which the particle is made. A species of higher density than spruce would tend to show less springback for pressed panels of equal specific gravity.

The strength properties of fiberboards and particle panels are directly influenced by density. Therefore, valid comparisons should be made on an equal specific gravity basis. Since the experimental panels involved a dispersion of density values, a sequence of data-treatment steps was necessary to arrive at a common basis of evaluation. This was done as follows: (1) Working plots of the strength-density relation for each particle type at each resin content were prepared, (2) slope lines that best conformed to the prevailing trends at each resin treatment level were estimated, and (3) from these slopes the strength-value intercept at a reference specific gravity was determined. In this program a working specific gravity of 0.80 was selected, as this was about the average for the entire series. A higher, or lower, reference density could be used, but with somewhat less confidence in the resultant strength comparisons for the whole group. Two examples of working plots are shown herein; figure 21 applies to the cube-based panels and illustrates divergent slope trends for the various resin contents. The collection in figure 22 shows the more prevalent type of data dispersion developed from the values in table 2. In a similar fashion working plots and slope estimations were made for the other particle-shape-based panels. From these plots an estimate was made of the prevailing form of the strength-density curve slope for each particle shape corresponding to the 4-percent resin-treatment level. An empirical linear equation of the form $Y = Mx + C$, was then calculated for each of these curves. A high value for M indicates a rapid gain in strength with increasing density, while the constant C, a theoretical modulus of rupture value at zero specific gravity, establishes the actual position of the slope line. These linear equation constants, corresponding to the different particles, are summarized in table 3.

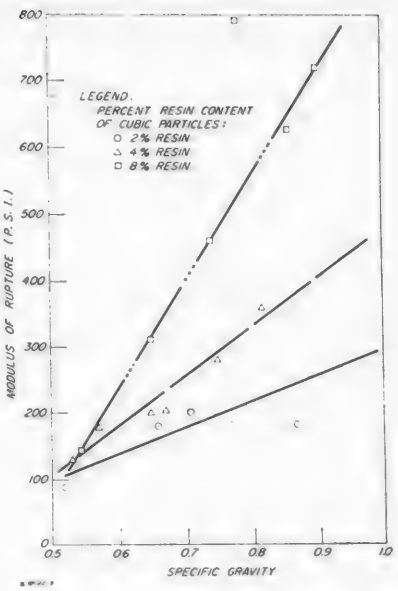


Figure 21.—Strength-density working plot for cube-shaped particles.

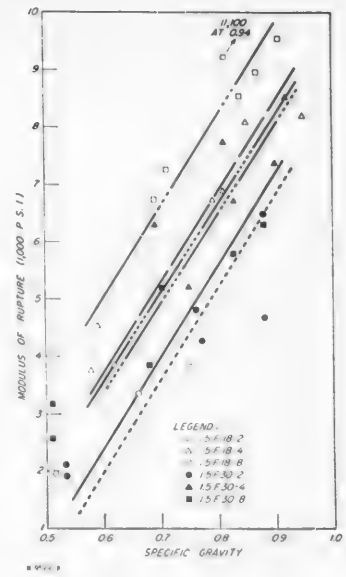


Figure 22.—Typical working-plot data dispersion for panels made from flat flakes of various thicknesses and resin contents.

The computed modulus of rupture values at specific gravity of 1.0 are listed here so that comparison of actual strengths can be made. Strength values corresponding to other densities may be readily calculated by using these equation forms. A word of caution is in order; these formulae were based on results from a limited number of test panels whose specific gravity range was generally between 0.5 and 1.05. Thus extrapolations beyond these density limits or attempts to make precise comparisons of actual values is inadvisable.

The curves in figure 23 summarize the strength-density relations derived from the series of working plots. These correspond to the 4-percent resin-treatment level for a variety of particle types. A similar array could be constructed for those panels bonded with 8 percent and 2 percent resin. The main effect of changing resin content is a displacement of the whole group rather than a rearrangement of curve positions. Thus further comparative elaboration in this vein would be repetitious. The degree of slopes, with the exception of curve 9, shows that the simple, direct avenue to higher strengths is to increase the panel molding pressure. For example, the particle shape of curve 4 (fig. 20) developed a modulus of rupture of 3,500 pounds per square inch at 0.50 specific gravity, while at double this density the strength is 8,500 pounds per square inch—or an increase of nearly 2.5 times due solely to the increased degree of compaction by higher pressure.

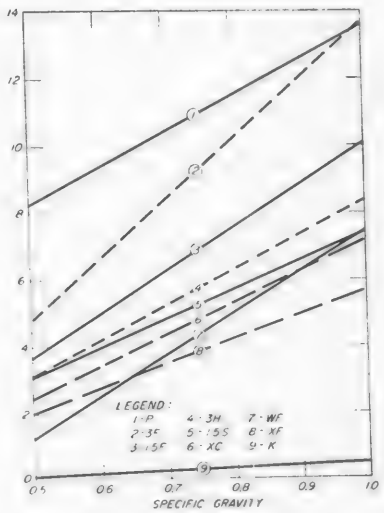


Figure 23.—Condensation of strength-density results for a variety of particle types.

1–P: Spruce, plywood, seven-ply, 0.042-inch veneer, cross-banded construction.

2–3F: Spruce, flat flake; 3" x 1" x 0.018", 4 percent resin content.

3–1.5F: Spruce, flat flake; 1.5" x 1" x 0.018", 4 percent resin content.

4–3H: Spruce, helix; 3" x 0.4" x 0.018", 4 percent resin content.

5–1.5S: Spruce, straight strand; 1.5" x 0.042" x 0.018", 4 percent resin content.

6–XC: Aspen, coarse-grade excelsior, 4 percent resin content.

7–WF: Aspen, coarse fiber (Wisconsin Wood Products Co.), 4 percent resin content.

8–XF: Aspen, fine-grade excelsior, 4 percent resin content.

9–K: Douglas-fir, cube shaped; 0.070" per side, 4 percent resin content.

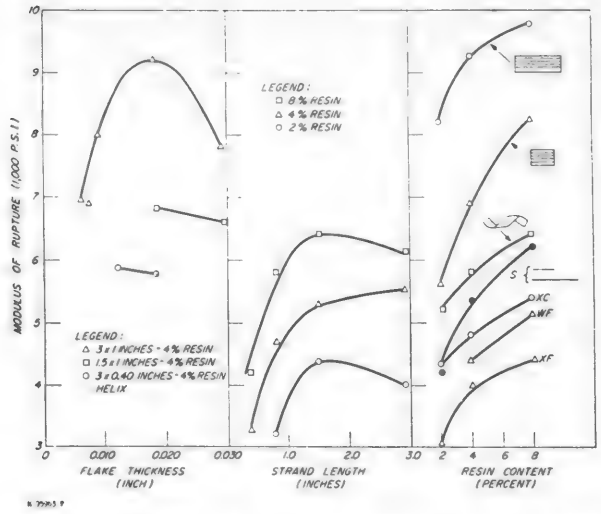


Figure 24.—Curves (above) showing effects on strength at 0.80 specific gravity of flake thickness, strand lengths, and resin content for several wood-particle shapes.

Following determinations of the strength-density relationships, the effect of flake thickness, strand lengths, and resin was readily established as shown in the curve assembly of figure 24. The maximum strength exhibited by the curve for the 3-inch flat flake at 0.015- to 0.020-inch thickness, shown at the top of the left frame, infers the probability of an optimum-strength-dimensional-resin-content relationship for each particle type. The location of this maximum range for other particle shapes and varying surface textures induced by species, moisture content, and cutting process variables, would constitute a significant amplification of these preliminary findings.

The results from strand-based panels show that length is of critical influence below about 1 inch (center frame, figure 24), but its effect is one of diminishing returns above 1.5-inch length. The strand-generation method used here was tedious, but it enabled critical study of some important handling features relevant to the length variable. The 1.5-inch strands were easily tumbled, sprayed, and formed into mats for pressing, whereas the 3-inch length intertwined and balled up in the mixer. A stationary breaker bar projecting into the tumbling drum was necessary to break up the large fiber masses tending to form during the spray treatment. Uniform distribution of the long strands in the mold frame was also troublesome. Although these are essential operational properties of the particle shape, they should not obscure other aspects of a particle's performance. For example, in this study bending strength was used as the sole structural criterion of particle performance, and on this basis a 1.5-inch strand was equal to a 3-inch strand. However, a wider scope of test methods, such as edgewise nail pullout, elastic modulus, impact resistance, screw-retention strength, and flexural fatigue quality, would provide a more accurate evaluation of the particle's total behavior pattern. There is an understandable tendency to sometimes make rather conclusive appraisals on the basis of test methods that, though meaningful, show only one facet of a multisided performance picture. Thus a skeptical outlook in making a final evaluation is appropriate in this instance.

The resin-content and particle-shape effects are delineated in the right frame of figure 24. The economic importance of resin demand per unit of resultant panel strength needs no clarification to those aware of the vital role that resin costs play in this process. The preponderant influence of particle geometry on strength is strikingly demonstrated in this array; the shape of particle is the controlling factor, while resin content is of secondary importance. The relative strength gains with increasing resin content are significantly different for the 1.5-inch and 3-inch flat flakes. This difference, which may be of technical importance, is probably a reflection of dissimilar length-width ratios since this is the major dimensional difference between these particles.

The extent of springback in panel thickness is governed by both resin content and the density prior to water soaking. For those particles of undamaged fiber structure, particle shape is of lesser importance than resin content. This observation is substantiated by the results charted in figure 25. It is of particular interest that those panels containing 4 and 8 percent resin show less springback than the plywood control. The flat flakes and coarse excelsior derived particles yielded panel-stability values essentially equal to that of plywood even at 2 percent resin content. The helix particle was definitely superior to plywood at the 2-percent resin level. This was not wholly unexpected; the helical ribbon possesses a unique fiber orientation system in that the grain direction varies not only in the plane

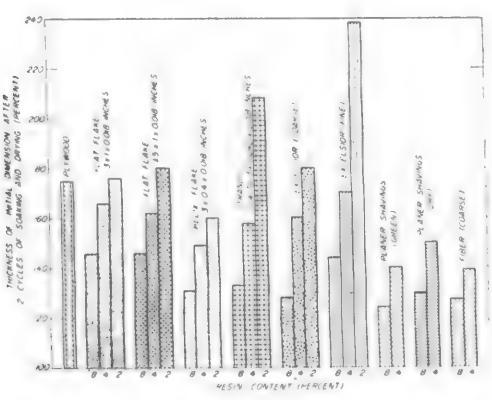


Figure 25.—Bar graph summarizing springback relationship to particle shape and resin content. These values correspond to test-panel specific gravity 0.80.

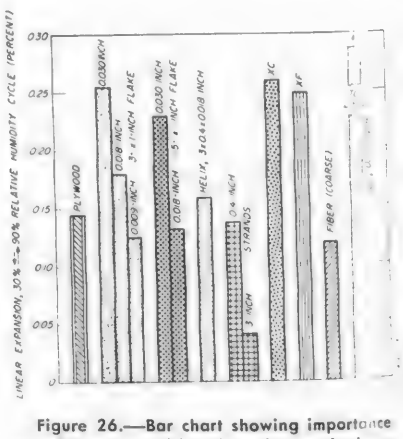


Figure 26.—Bar chart showing importance of effect of particle dimension and shape on lineal expansion during cyclic humidity exposure.

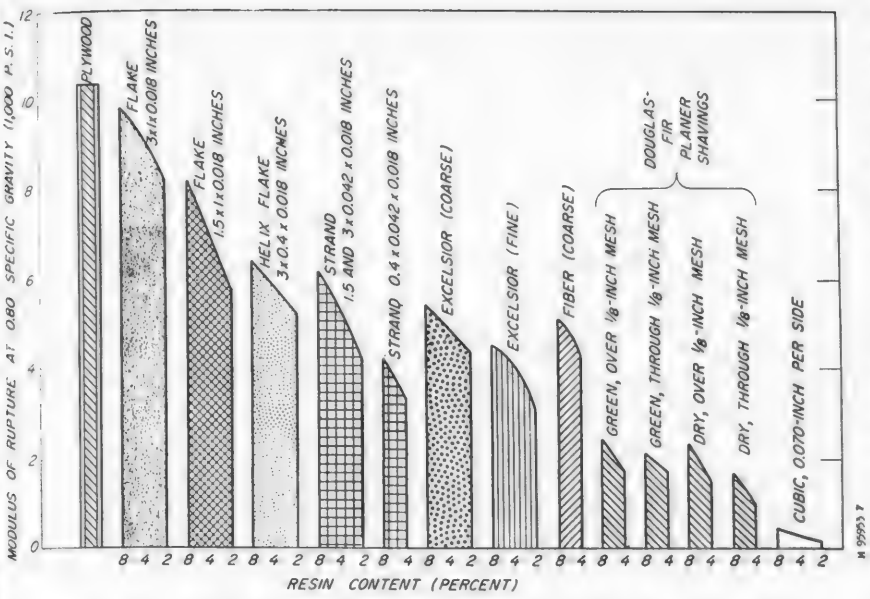

MODULUS OF RUPTURE AT 0.80 SPECIFIC GRAVITY (1,000 P.S.I.)
PLYWOOD
FLAKE 3 x 1 x 0.018 INCHES
FLAKE 1.5 x 1 x 0.018 INCHES
HELIX FLAKE 3 x 0.4 x 0.018 INCHES
STRAND 1.5 AND 3 x 0.042 x 0.018 INCHES
STRAND 0.4 x 0.042 x 0.018 INCHES
EXCELSIOR (COARSE)
EXCELSIOR (FINE)
FIBER (COARSE)
DOUGLAS-FIR PLANER SHAVINGS
GREEN, OVER 1/8-INCH MESH
GREEN, THROUGH 1/8-INCH MESH
DRY, OVER 1/8-INCH MESH
DRY, THROUGH 1/8-INCH MESH
CUBIC, 0.070-INCH PER SIDE
RESIN CONTENT (PERCENT)

Figure 27.—Chart (right) summarizing effects of resin content and particle shape upon strength, when referred to a common specific gavity of 0.80.

of the sheet but also in the thickness dimension of the panel. This disposition of fiber directions, within every particle, probably accounts for the superior thickness stability and would reasonably forecast that the mechanical properties would be more nearly isotropic than those from panels based on particles whose fibers lie in one plane. The planer-shavings-based boards, though inferior in bending strength, perform well in the springback test. However, this is a biased comparison, since these shavings, of Douglas-fir, had a higher initial density than the comparison particles of spruce and aspen.

Linear expansion in the plane of the sheet induced by changes in fiber moisture content is an important property of wood-based panel materials. The stability of plywood in this regard is well recognized, while the instability of some other wood-origin sheet products often requires careful consideration of design details or limits the fields of application even though the structural requirements are exceeded. The reference panel of spruce plywood expanded about 0.14 percent in the plane of the sheet during exposure to a cycle from 30 percent relative humidity to 90 percent relative humidity. This result compares favorably with a value of 0.15 percent obtained by B. G. Heebink of the U. S. Forest Products Laboratory on 4-foot panels of 1/4-inch Douglas-fir plywood.

The summary of data given in the bar chart of figure 26 shows that not only particle shape but also dimensional variables within a particle class influence linear expansion. The correlation of dimensional stability with flake thickness and strand length is noteworthy. The overwhelming contribution of sound fiber structure in the particle is obvious in the comparison of cube-based panels with panels made from the helix ribbon, for example. The linear expansion traceable to the cubic element is on the order of 20 times more than that arising from particles whose fiber structure is intact. The contrasting performance of the straight strands, the excelsior particles, and the coarse fiber is of unusual significance. These were all geometrically similar particles. An explanation of the exceptional behavior of the excelsior-based panels would probably require microscopic examination of the actual particles used, since it is conjectured that fiber damage, not readily apparent to the unaided eye, is the cause of the inferior performance shown. Fiber breakage in these particles may have occurred in the hammer-milling preparation step, but the mechanics of the generation process may be a more likely source of fiber damage.

The final chart, figure 27, summarizes both particle-shape and resin-content influence upon modulus of rupture. These values correspond to a common specific gravity basis of 0.80. The superior particle types yield panels that approach plywood in strength properties, especially at the highest resin content of 8 percent. The 1.5-inch flat flake, 3-inch helix, and strands above 1.5 inch long, though not so intrinsically strong as the 3-inch flat flake, nevertheless produce panels with relatively good structural properties. It is fitting to reiterate that these test data provide only a partial view of the varied mechanical properties that can be anticipated from a diversity of particle shapes, methods of panel formation, and bonding-resin characteristics. The range of stability and strength values shown is evidence that a broad survey of particle structural quality was made. The ultimate potential, plywood, was closely approached at one extreme, while the weakest test panel based on a cubic particle had to be handled with care to keep it intact for test purposes.

Summary

Particle shape and dimensional factors were correlated with their derived panel properties by means of three test methods: (1) Modulus of rupture at 65 percent relative humidity, (2) thickness change, or springback, following two cycles of watersoaking, ovendrying, and (3) linear expansion during cyclic, equilibrium exposure to 30 percent and 90 percent relative humidity.

The specially made particles, in most instances characterized by a minimum of fiber damage, comprised rectangular flat flakes varying from 0.006 inch to 0.030 inch thick, 45° pitch helical ribbons about 1/2 inch wide by 3 inches in fiber length, and a series of straight strands whose cross sections were the same, 0.042 inch by 0.018 inch, but of controlled lengths of about 3/8, 3/4, 1 1/2, and 3 inch. A shape devoid of fiber quality in the form of 1/16 inch cubic particles provided the minimum extreme of structural performance. In addition to these precisely made particle types, a series of fibrous materials derived from commercial grades of excelsior and a coarse, mechanically made fiber were evaluated. A typical mill waste, planer shavings from Douglas-fir lumber, was included as a part of the comparison.

Particle generation methods included the following: (1) Hammer-milling followed by rotary-screen classification (excelsior fibers and veneer slivers), (2) Wiley-mill reduction of thin, end-grain wafers followed by screen fractionation (cubic particles), and (3) controlled cutting by using a rotary cutterhead on a modified milling machine. The latter method was not only versatile as to particle dimensional control and configuration, but also capable of substantial production rates. Flat flakes, varied-pitch helical ribbons, tubular, tapered cross-section flakes, and uniform strands in either straight or helix form were prepared in the course of a brief survey of the cutting-process variables.

From the above array of particle forms, a few were selected for intensive evaluation. These were spray treated with a water suspension of pulverized phenolic resin. Treatment levels, based on the dry weight of wood particles, were 2, 4, and 8 percent resin. Hot-press molding was done at 3 pressure levels, 250, 500, and 1,000 pounds per square

Table 2.--Summary of results of tests of resin-bonded wood-particle panels

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained: cycles of soaking, drying Δt	Thickness change after 2 cycles to 90% relative humidity: ΔL	Linear expansion from 30% to 90% relative humidity: ΔL
		Percent		P.s.i.	Percent	Percent	Percent
1	3F6	4	0.73	6,770	75	70	
2			.76	8,960	87	43	0.101
3			.83	4,220	116	42	
4			.80	6,300	69	50	
5			.96	10,110	97	26	.122
6							
7	3F6	8	.75	6,090	131	33	
8			.79	8,310	109	38	.107
9			.82	6,850	128	34	
10			.86	10,430	109	37	.123
11			.95	9,300	91	23	.142
12							
13	3F6	2	.80	5,260	87	50	.130
14							.238
15	3F9	2	.65	2,010	50	87	
16							
17			.72	4,090	66	53	
18			.77	4,710	97	77	.130
19			.85	5,480	83	74	
20	3F9	4	.87	4,760	143	80	.099
21			.60	4,520	95	43	
22			.59	3,800	81	37	.116
23			.68	5,780	93	48	
24			.68	4,760	108	37	.138
25			.89	9,940	115	66	
26	3F9	8	.78	6,280	105	62	.111
27			.65	6,440	113	35	
28			.63	5,090	134	24	.138
29			.78	9,960	112	36	
30			.84	8,340	148	46	.124
31			.84	9,540	122	41	
32			.88	12,500	112	46	.125
33	3F18	2	0.72	7,000	76	59	
34			.65	5,170	68	65	0.140
35			.76	6,690	121	75	
36			.75	6,900	131	73	.195
37			.90	9,740	130	50	
38			.86	10,290	92	62	
38A			.88	9,280	117	76	
39	3F18	4	.64	5,200	147	50	
40			.65	5,940	105	56	.115
41			.78	9,920	101	57	
42			.82	9,740	144	66	.156
43			.89	11,380	136	74	
44			.88	10,190	153	74	.104
45	3F18	8	.71	9,020	113	45	
46			.80	8,220	144	45	.154
47			.83	10,880	110	46	
48			.78	8,900	129	41	.149
49			.86	9,560	133	44	
50			.89	12,760	99	45	.170
51	3F30	4	.73	6,890	149	62	
52			.76	4,930	197	70	.260
53			.76	6,910	152	78	
54			.84	9,720	124	69	.244
55			.92	11,160	130	71	
56			.89	8,610	136	72	.275
118	3F30	8	.75	7,530	118	40	
278			.57	5,360	71	30	.197
279			.78	5,310	181	57	
119			.88	9,440	129	49	
281			.76	3,260	184	42	.917
112	3F30	2	.55	4,400	65	40	
113			.58	4,410	66	42	.230
114			.83	7,350	161	84	
115			.87	9,630	118	82	.258
116			.85	6,196	97	83	
117			.89	7,940	113	81	.265
256	3F7	2	0.60	3,000	54	56	
257			.50	1,180	67	45	0.0
258			.79	5,080	77	74	
259			.80	6,810	80	62	
260			.93	8,140	112	73	
261			.88	7,760	100	70	
262	3F7	4	.56	2,190	79	55	
263			.53	1,690	76	37	
264			.71	4,330	102	52	
265							
266			.89	8,020	137	63	
267			.95	9,390	113	50	
268	3F7	8	.63	4,040	94	34	
269			.56	4,270	68	31	
270			.73	6,530	108	37	
271			.70	7,100	86	28	
272			.82	7,880	126	49	
273			.79	8,990	111	30	
P1	Seven-ply Sitka spruce plywood		.60	7,640	115	41	
P2			.85	11,560	133	82	
P3	0.042-inch		.98	12,970	126	87	
P4	veneer, film		1.04	14,380	102	48	
P5	glue		1.22	17,340	88	11	
P6			1.21	16,410	90	15	

Table 2.--Summary of results of tests of resin-bonded wood-particle panels (continued)

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained: cycles of soaking, drying Δt	Thickness change after 2 cycles to 90% relative humidity: ΔL	Linear expansion from 30% to 90% relative humidity: ΔL
		Percent		P.s.i.	Percent	Percent	Percent
288	1.5P18	2	0.43	720	69	62	
289			.42	700	50	89	0.278
290			.66	3,320	83	59	
291			.62	3,880	78	50	.200
292			.75	3,810	135	76	
293			.75	3,900	73	76	.168
69	1.5P18	4	.58	3,780	81	43	
70			.59	4,550	61	34	.145
71			.79	6,740	137	64	
72			.81	6,910	121	62	.170
73			.85	8,120	123	62	
74			.95	8,220	158	69	.160
75	1.5P18	8	.71	7,260	90	38	
76			.69	6,780	88	35	.116
77			.86	8,960	113	53	
78			.84	8,550	90	43	.111
79			.91	9,570	114	33	
80			.94	11,080	98	55	.144
87	1.5P30	2	.53	2,110	64	62	
88			.53	1,960	62	65	.234
89			.77	4,290	122	74	
90			.76	4,830	142	84	.244
91			.88	6,480	105	86	
92			.80	4,700	108	80	.234
81	1.5P30	4	.75	5,260	134	67	
82			.69	6,340	44	47	.189
83			.83	6,760	108	67	
84			.81	7,750	98	73	.225
85			.92	8,540	139	71	
86			.90	7,390	81	59	.228
282	1.5P30	8	.51	2,570	89	17	
283			.49	3,100	60	16	.229
284			.68	3,850	115	52	
285			.70	5,260	117	52	.280
286			.83	5,770	124	54	
287			.88	6,340	128	58	.211
178	3H12	2	0.66	2,710	69	58	
274			.47	980	30	57	0.228
179			.87	5,420	91	53	
275			.73	2,940	95	55	.178
180			1.03	7,960	91	60	
181			1.04	8,040	82	59	.189
182	3H12	4	.64	4,410	88	30	
276			.51	1,930	69	20	.178
183			.90	8,150	92	41	
184			.94	7,930	104	36	.082
277			.92	7,160	100	47	
185			1.00	7,610	117	34	.095
186	3H12	8	.73	5,480	111	22	
187			.70	5,420	90	33	.132
188			.92	9,300	107	27	.118
189			1.01	10,940	97	23	.142
190	K	2	.52	90	Panels disintegrated on soaking to dry cycle test used to determine these values	2.74	
191			.48	80		2.88	
192			.66	180			
193			.71	200			
194			.77	180			
195			.87	180			
196	K	4	.53	130		2.58	
197			.57	180			
198			.65	200		2.75	
199			.67	200			
200			.82	360		2.82	
201			.75	280			
202	K	8	.54	140		2.34	
203			.65	310			
204			.78	800		2.65	
205			.74	460			
206			.90	720		2.69	
207			.86	630			
294	0.8S	2	.50	1,010	41	139	.064
295			.72	2,410	86	57	.062
296			.82	2,900	117	103	.084
130	0.8S	4	.62	2,820	85	67	
131			.64	3,000	79	61	.042
132			.81	4,880	98	70	
133			.77	4,080	102	57	.12
134			.96	7,500	96	58	
135			.95	5,790	126	54	.143
136	0.8S	8	.61	3,470	61	39	
137			.73	4,810	110	31	.08
138			.89	7,120	106	36	
139			.90	7,940	94	38	.00
140			1.03	8,410	90	30	
141			1.01	7,640	99	17	.082

inch; resultant panel specific gravities were from about 0.50 to 1.05.

Within the same particle class it was found that panel density has a direct and large effect upon physical properties. Density is of primary influence, resin content secondary in controlling actual strength properties. When the data are analyzed to permit comparison on a common density basis, the relative behavior of unlike particles is clarified; particle configuration and its dimensions exert dominant control over both structural- and dimensional-stability qualities. At the reference specific gravity of 0.80, an undamaged, long flat flake gave panels nearly equal to plywood; modulus of rupture values of about 10,000 pounds per square inch were obtained with 8 percent resin content, while a decline to only 8,000 pounds per square inch occurred when the resin was reduced to 2 percent. A helical ribbon and a 3-inch thin strand, whose panels were infer

Table 2.--Summary of results of tests of resin-bonded wood-particle panels (continued)

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained	Thickness change after 2 cycles of soaking, drying Δt	Linear expansion from 30% to 90% relative humidity ΔL
		Percent		P.s.i.	Percent	Percent	Percent
172	1/	2	0.52	1,110	52	159	
173			.54	1,880	65	98	0.028
174			.77	3,330	117	101	
175			.80	3,620	106	92	.184
176			.94	7,670	91	71	
177			.94	6,270	108	76	.162
178							
142	1/	4	.95	6,280	89	41	
143			.59	3,610	60	64	.087
144			.86	6,400	89	66	
145			.76	4,300	133	55	.076
146			.98	8,230	99	45	
147			.97	6,970	117	35	.095
148	1/	8	.66	4,060	118	34	.066
149							
150			.86	8,240	81	29	
151			.85	8,180	84	39	.066
152			.95	7,100	111	27	.099
153							
154	3/	2	.54	1,330	48	177	
155			.55	1,540	79	120	.072
156			.74	2,530	85	138	
157			.75	5,120	80	102	.040
158			.86	4,200	90	101	
159			.87	5,050	78	110	.075
160							
57	3/	4	.51	2,220	91	48	
58			.48	2,230	83	49	.018
59			.72	3,880	112	57	
60			.71	5,230	86	48	.020
61			.91	7,750	103	50	
62			.86	5,820	102	51	.022
63							
166	3/	8	.59	3,000	97	39	
167			.54	2,300	137	41	.004
168			.82	7,880	91	29	
169			.90	6,220	96	27	.040
170			.94	9,680	100	16	
171			.98	8,000	102	11	.091

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained	Thickness change after 2 cycles of soaking, drying Δt	Linear expansion from 30% to 90% relative humidity ΔL
		Percent		P.s.i.	Percent	Percent	Percent
63	3S	4	0.55	1,930	104	49	
64	0.042 x		.56	1,780	96	46	0.038
65	0.030		.79	4,560	118	49	
66			.73	4,590	115	45	.066
67			.91	6,790	89	47	.090
68							
244	WF	4	.62	2,610	89	35	
245			.66	2,020	112	32	.096
246			.84	4,680	78	46	.134
247							.168
248			1.00	7,640	93	39	
249			1.00	7,350	74	46	
250	WF	8	.70	3,680	92	17	
251			.71	4,020	91	18	.098
252			.92	7,060	95	33	
253			.89	7,980	94	27	.120
254			1.05	8,060	101	45	
255			1.03	7,260	118	20	.118
94	3H18	2	.57	2,770	60	41	
95			.55	1,660	77	43	.136
96			.80	4,930	79	70	
97			.81	4,900	82	65	.100
98			.98	7,200	97	73	
99			.98	8,950	85	73	.142
100	3R18	4	.71	4,590	116	47	
101			.65	5,020	95	31	.146
102			.86	6,870	101	56	
103			.86	6,320	117	51	.172
104			.96	7,760	117	60	
105			.96	7,950	132	49	.189
106	3H18	8	.55	3,140	94	13	
107			.56	3,240	103	14	.132
108			.85	7,260	102	45	
109			.85	7,800	85	38	.196
110			1.00	8,870	105	38	
111			.98	7,980	114	37	.225

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained	Thickness change after 2 cycles of soaking, drying Δt	Linear expansion from 30% to 90% relative humidity ΔL
		Percent		P.s.i.	Percent	Percent	Percent
208	XC + 1/8-inch mesh	2	0.60	1,900	48	71	
209			.58	1,300	78	69	0.246
210			.84	4,740	86	84	
211			.84	5,060	77	96	.284
212			.92	5,610	81	87	
213			.96	5,240	88	86	.268
214	XC + 1/8-inch mesh	4	.68	3,760	86	49	
215			.69	3,360	94	55	.220
216			.93	4,610	120	78	
217			.89	4,450	149	77	.266
218			.96	6,610	107	47	
219			1.01	7,740	115	53	.302
220	XC + 1/8-inch mesh	8	.68	3,840	88	26	
221			.58	2,470	83	16	.222
222			.90	6,860	102	36	
223			.87	4,460	131	33	.252
224			1.00	8,680	97	27	
225			.99	7,420	92	32	.276
226	XF + 1/8-inch mesh	2	.57	870	24	205	
227			.56	1,340	50	119	.225
228			.77	2,390	73	133	
229			.77	3,060	89	88	.270
230			.92	3,360	82	165	
231			.95	4,490	101	154	.269
232	XF + 1/8-inch mesh	4	.60	1,880	94	50	
233			.63	3,940	77	61	.222
234			.84	4,220	85	99	
235			.82	4,300	86	57	.211
236			.95	5,240	106	68	
237			.95	4,570	138	82	.311
238	XF + 1/8-inch mesh	8	.62	2,300	86	61	
239			.66	2,580	120	40	.182
240			.89	6,170	100	50	
241			.89	4,960	99	39	.204
242			.88	5,360	107	40	
243			1.06	6,910	119	32	.254

Table 2.--Summary of results of tests of resin-bonded wood-particle panels (continued)

Panel No.	Particle symbol	Resin content	Specific gravity	Modulus of rupture	Load capacity retained	Thickness change after 2 cycles of soaking, drying Δt	Linear expansion from 30% to 90% relative humidity ΔL
		Percent		P.s.i.	Percent	Percent	Percent
300	Dry planer shavings over 1/8-inch-mesh rotary screen [1]	4	0.60	670	70	41	Not determined
301			.61	620	82	50	
302			.80	1,680	61	52	
303			.77	1,120	59	54	
304			.95	2,210	48	55	
305			.98	2,620	56	60	
306		8	.68	1,540	72	24	
307			.66	1,060	78	34	
308			.87	2,990	67	32	
309			.85	2,440	66	33	
310			1.09	4,920	67	36	
311			1.08	4,550	79	32	
312	Dry planer shavings through 1/8-inch-mesh rotary screen	4	.64	470	38	39	Not determined
313			.62	420	33	44	
314			.70	870	53	48	
315			.74	805	37	49	
316			.95	1,600	39	59	
317			.93	1,480	42	60	
318		8	.68	880	52	21	
319			.62	640	62	21	
320			.90	2,700	65	25	
321			.80	1,520	66	32	
322			1.04	4,080	35	38	
323			.95	2,650	86	27	
324	Green planer shavings over 1/8-inch-mesh rotary screen	4	0.58	830	58	36	Not determined
325			.54	550	65	42	
326			.76	1,870	54	45	
327			.67	1,200	93	51	
328			.98	3,050	52	52	
329			.90	2,320	89	52	
330		8	.65	1,300	74	30	
331			.70	1,580	80	40	
332			.92	3,340	66	31	
333			.76	2,300	62	31	
334			1.07	4,960	49	30	
335			1.08	4,710	61	31	
336	Green planer shavings through 1/8-inch-mesh rotary screen [2]	4	.54	550	51	30	Not determined
337			.60	960	40	32	
338			.81	2,000	45	41	
339			.69	1,210	65	37	
340			.90	1,930	91	48	
341			1.02	3,250	40	55	
342		8	.60	1,070		25	
343			.61	1,270	46	18	
344			.76	1,960	96	32	
345			.77	1,740	94	29	
346			.97	2,930	104	28	
347			1.02	3,840	79	33	

[1] Raw material supplied by Weyerhaeuser Timber Co.
Species: Coast-type Douglas-fir.

[2] These data on panel Nos. 300 to 347 extracted from previous unpublished report; resin-bonded hardboard and core stock from Douglas-fir planer waste.

Table 3.—Modulus of rupture-specific gravity relation constants for selected experimental particle boards

Particle classification	Dimensions	Resin	Slope M[1]	Constant C	Calculated modulus of rupture at 1.00 specific gravity
	Inch	Percent	P.s.i.	P.s.i.	P.s.i.
Plywood: 7-ply	0.042 veneer	.....	14,900	-1,300	13,600
Flat flake	3 x 1 x 0.018	4	22,500	-8,700	13,800
Do.....	1.5 x 1 x 0.018	4	16,000	-5,900	10,100
Helix flake	3 x 0.4 x 0.018	4	13,200	-4,800	8,400
Thin strands	1.5 x 0.042 x 0.018	4	10,700	-3,290	7,410
Cubic	Approximate 0.070	2	400	-105	300
Do.....	per side	4	600	-280	480
Do.....		8	1,600	-720	880
Excelsior	Coarse grade	4	11,900	-4,700	7,200
Do.....	Fine grade	4	9,400	-3,500	5,700
Fiber	Coarse	4	15,500	-8,000	7,500
Planer shavings: Douglas-fir	Dry: over 1/8-inch mesh	4	5,200	-2,500	2,700
	Green: over 1/8-inch mesh	4	8,300	-4,150	4,150

[1]Equation form is: R = M (D) + C: where: R is modulus of rupture: p.s.i.
M is slope of curve: p.s.i.
D is specific gravity
C is constant: p.s.i.

to the flat-flake panels in bending strength, yielded definitely superior dimensional-stability properties. Those particles that showed evidence of fiber damage or were seriously lacking in fiber quality displayed a comparatively high linear expansion. The importance of fiber structural integrity is underlined by the exceedingly poor behavior, in this respect, of the cube-based material, whose expansion was 10 to 20 times more than that of panels made from particles having sound fibers.

The resin content is a governing factor, within a given particle class in the springback behavior. Since this test employs fixed exposure cycles—16-hour water immersion and 8-hour ovendrying—rather than equilibrium conditions, the effect may be actually one of rate retardation rather than an indication of long-run performance under severe exposure. The necessity for qualified interpretation of test data is emphasized by this example.

These findings, though comprehensive in some aspects, should be viewed mainly as an introduction to the panorama of the field that can be visualized. The range of particle types and their dimensional variation has been only briefly surveyed in this work. The limited scope of test methods necessarily used herein served as a convenient preliminary evaluation. Such properties as machinability, screw retention, toughness, stiffness, paintability, and esthetic features were perforce ignored in this research, yet these qualities are often of outstanding importance for particular end uses. Thus it appears that there is ample opportunity for development of numerous special-purpose particles for a variety of panel applications and molded structural products. A vigorous industrial expansion of the bonded-particleboard field can be foreseen as our knowledge of basic relationships grows. The fruits of this understanding will be manifest in new and abundant materials from what is now a largely wasted resource.

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Discussion

Geo. G. Marra (Washington State Institute of Technology): The research reported in this paper is of a type sorely needed by the "dry-board" movement. Although the dry processes are recognized as having wide potential application in the utilization of various forms of wood residues, they have not enjoyed the same rapid progress which has characterized the growth of the wet process hardboard industry. One of the principal reasons for this situation is the lack of a body of fundamental knowledge comparable to that supporting the wet fiber processes. Practically every question which has arisen in connection with dry processes has necessitated laboratory experimentation to enable process development to proceed. There has been no large volume of reliable data available on which to base "educated guesses" which permit a faster screening of ideas and faster exploitation of sound leads. Against the background of literature presently available on this general subject, Mr. Turner's work stands out as a model of

thoroughness, ingenuity, and clearness in interpretation of data. It will have an unassessable snow-ball effect in advancing future research and progress in this field.

As with most research, this work developed some unanswered questions. Although Mr. Turner sought to avoid speculation in setting forth reasons for some of the interesting effects observed in his experiments, such speculation at this level of scientific inquiry may be helpful in orienting the thinking of others who may be concerned with the same problems. The following comments are largely in the nature of speculation and it is hoped that they will incite more of the same.

The results obtained with large rectangular flat particles are particularly intriguing. Because of special methods of preparation, these particles have high inherent strength and also have smoother and less damaged surfaces which permit better bonding action at lower pressures. As Mr. Turner has demonstrated, this type of particle permits the manufacture of high strength boards at medium densities and minimum resin content.

Of the three dimensions defining the size of these particles—length, thickness and width—the role of length appears to be the most readily deduced. Length of particle determines the number of contacts which each particle will have with other particles and thus controls the degree to which the inherent strength of the individual particles is transferred to the board as a whole. Optimum length is related to a balance of particle strength and contact area necessary to transfer this strength to the adjacent particles. Excess length, as Mr. Turner found, contributes to the problems of board formation, although the latter problems may well begin before the optimum length for strength is reached. Mr. Turner's conclusion that the optimum length may lie between 1.5 inches and 3.0 inches is reasonable, but ease of board formation with mechanical equipment in the present state of development may reduce the tolerable length below 1.5 inches.

The role of flake thickness seems to be many-sided. It is associated with such factors as surface quality generated during particle formation, surface area-volume relationships, particle pliability, resin efficiency on edge and end surfaces, final board densities, and voids throughout the board and on the surface. Thickness is the most potent of the dimensions in its effect on the surface area per unit of volume of the particles. Doubling the thickness of particles, for example, results in approximately a 37 percent reduction in surface area per unit volume (or unit weight) of particles with a corresponding increase in resin concentration on the surfaces when resin content is computed on a weight basis. Doubling the thickness, of course, also doubles the unfruitful edge and end surfaces which tends to subtract from the total resin efficiency. On the whole, it would appear that thicknesses beyond an undefined minimum tend to compound negative factors faster than the favorable factors if strength and resin efficiency are the prime considerations. If requirements for low density over-ride other properties, greater flake thicknesses are helpful.

In Mr. Turner's long-flake series, maximum strengths appear to have been obtained at 18 mils thickness while at 30 mils and 9 mils the boards reflected decreased strengths. The 30-mil flakes probably revealed the effects of the array of negative factors overbalancing the apparent gain in resin concentration. The 9-mil flakes, on the other hand, may have suffered less from the negative factors, but also had the least advantage from resin concentration. Of particular interest is the fact that the 9-mil flakes were most sensitive to resin levels which indicates that these flakes provide more fruitful contact areas for the resin to perform its function. The 9-mil flakes also appear to display better dimensional stability which is probably due in part to the greater randomness permitted by the larger number of particles making up the thickness of the board.

The last dimension to be considered is width of particles. Increases in the width dimension of the particle lowers the ratio of surface area to volume, although not as rapidly as varying the thickness dimension and more so than varying the length dimension. Increasing the width in the manner of veneer to infinite width, assuming constant length and thickness, would generate a minimum surface area-volume ratio. Starting with a particle having width equal to thickness, it can be shown mathematically that 50 percent of all the advantage of minimum surface area-volume at infinite width is obtained when the width equals twice the thickness. Ninety percent of this advantage is obtained when the width equals ten times the thickness. Hence, it would appear that from the standpoint of resin efficiency, about 10 T is the limit on width. Aside from the effect of width on resin efficiency, the width-strength factor is a complex relationship which merits further study. It is possible that width of particles *per se* has very little effect on board strength. This reasoning is based on two assumptions: 1) The total tensile strength of individual particles parallel to the grain varies with width in direct proportion to the flat surface area which is primarily responsible for transferring this strength to the board, (e.g., consider the analogous relationship of members of a plywood tensile specimen); and 2) the tensile strength of individual particles perpendicular to the grain does not vary with width. Particle widths in excess of 10 T, therefore, may be desirable primarily for decorative aspects or possible greater ease in handling and board forming, the latter because of the fact that there is likely to be less intertwining and "balling up". Principal disadvantages of excess width are the tendency of the particles to fracture along the grain during necessary handling, thus producing narrower particles, and the tendency for particles to shield each other during resin application.

Mr. Turner did not use width as a variable in his flake series, but his standard width of 0.95 in. was beyond 10 T for all thicknesses.

In speaking of resin efficiency it is important to keep in mind that this factor has a number of facets all of which relate to board performance per unit of resin content, such as: 1) resin concentration per unit surface area of particles, 2) resin wastage on end and edge surfaces of particles, 3) actual contact area available with adequate pressure for the resin to consumate its function of developing a firm bond between particles, 4) quality of particle surface for resin to perform adhesive function.

As Mr. Turner points out, the host of variables involved in particle board manufacture and their effect on the many pertinent physical properties have been investigated only briefly in research to date. Truly, much opportunity exists for productive research effort in this field and for ingenious application of basic knowledge as rapidly as laboratories can make it available.

The Manufacture of General-Purpose and Decorative Pressed Wood Boards by a Dry Process

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Factors leading to a decision in favor of manufacture of pressed wood boards by a dry process at a western sawmilling and woodworking operation are discussed. The general outlines of the process developed to fit the Company's particular needs and conditions are given as well as a description of the versatile line of new board products manufactured.

Introduction

THE BASICALLY most significant and far-reaching development in the wood utilization industries today from the standpoint of annual tonnage and value of product likely to be produced in the foreseeable future is the widespread trend toward conversion of waste wood into pressed-wood-board products. The main causes responsible are: (1) the large and unavoidable waste factor, of the order of one-half the raw material volume, in the conversion of logs into lumber and plywood; (2) the rapidly growing national and world need for board products for building construction and for a host of manufactured articles. In the latter connection, the need is rapidly overtaking and promises to outstrip the capacity of the forests to supply board material in the form of lumber, plywood, and paperboard products. The decreasing supply of timber relative to demand, and the resultant increasing price, or value, of timber, constitute a strong force in the direction of converting the waste or poorly utilized half of the log into valuable board products. These forces are of course operative in the various sawmills, plywood plants, and factories of the Long–Bell Lumber Company, and the present paper can be taken as a brief case history of one company's response to the situation. This involved the development of a dry process, and the purpose here is to explain in a broad way the factors leading to its choice and development and the general nature of the process, and to describe some of the products.

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Factors in Choice of Manufacturing Method

The particular complex of needs and conditions existing for Long–Bell may be summarized as follows: The Company has several widely different manufacturing operations producing raw materials conceivably suitable for large-scale pressed-board manufacture. At Longview, Washington, is one of the country's largest sawmilling and planing mill operations including a factory producing softwood furniture and prefabricated cabinetwork; on the Oregon Coast, two sawmilling and planing mill operations and a plywood plant; in west central Oregon, two smaller fir

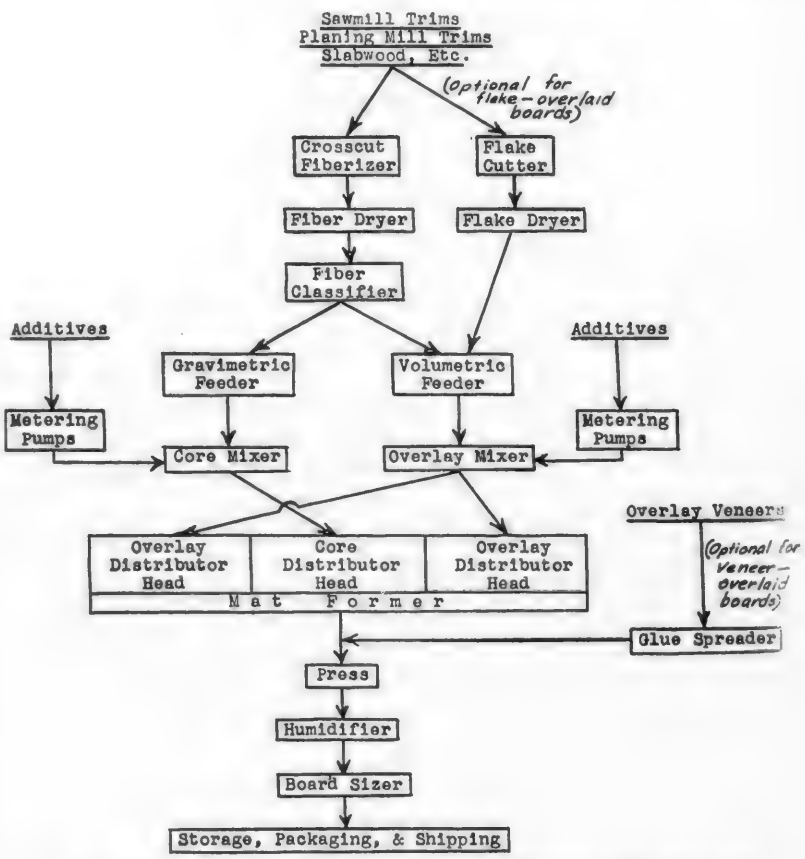

Figure 1.—Flow chart of Long–Bell Lumber Company pressed-wood board plant.

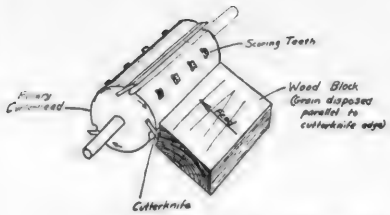

Figure 2.—Basic cutting arrangements for producing Long–Bell crosscut fiber and crosscut wood flakes. (Patents pending)

sawmilling and planing mill operations; and in northern California, a large ponderosa pine operation including a sawmill, planing mill, plywood plant, sash-and-door plant, and box factory. At each of these locations, manufacturing left-overs both in the form of solid wood and in comminuted forms such as planer shavings and sawdust are produced in sufficient daily tonnage to conceivably support a board plant. Efficiency of raw material utilization at these plants is as good if not substantially better than the average for the industry. A large part of the potential pressed board raw material is at present utilized as fuel, which of course represents extremely low values compared with the other products derived from the log. These operations vary widely as to the amount and kind of potential raw material, fuel and power situation, water supply, stream pollution hazard, etc.

On the sales side of the picture, the Company operates numerous and widely distributed retail lumber yards and maintains a large selling organization for lumber, plywood, and factory products, which is available for the distribution and sales of pressed wood boards.

The basic decision was early reached that the Longview operations should be the location for the first venture into the field of pressed board manufacture. The factors favoring this location as well as disadvantages are as follows:

(1) The desire of the Company's management to gain a further increase of the efficiency of wood utilization at these operations, an increase which would constitute a basic advantage in maintaining a continuous large timber supply required here to help assure stability of the operations and of the Company-founded city of Longview; (2) A favorable and easily accessible power and steam supply; (3) A large mixed-car business with company and non-company retail yards originating from the shipping department at Longview; (4) The presence of a factory manufacturing kitchen cabinets, chests, and other fabricated wood articles which could be counted on to advantageously consume a substantial part of board plant output; (5) A large supply of a variety of potentially suitable raw materials, available in amounts running in hundreds of tons per day; (6) A long-term commitment (on the debit side of the raw materials account) to supply pulp chips, which makes unavailable the best chippable material at this operation, and which eliminates wet-processes from consideration; (7) A research finding which made it possible to manufacture fiber suitable for dry-process pressed boards from alternative materials available at the operation, such as kiln-dried "planer ends".

The last-mentioned factor also made possible the main approach of the whole project, which was to develop a process which could be used to manufacture a versatile line of boards in various thicknesses from 1/16-inch to ¾-inch and with a wide range of decorative appearance and technical properties. In connection with the decorative boards, the aim was to retain as much as possible the color, appearance, and decorative values of natural wood. This is in contrast with the conventional hardboards, which lose their wood appearance and more nearly resemble the paperboards. It was felt that a class of boards with an attractive composite of appearance and properties could easily find at least a modest market niche of its own.

Description of Manufacturing Method

The general outline of the manufacturing steps is shown in the flow chart, Fig. 1.

As might be expected, the manufacturing details have points of similarity with as well as differences from the other dry processes for fibrous-particle and granular-particle boards at present disclosed in the rapidly developing technology of pressed-wood board manufacture. The most significant difference is found in the method of fiber production. The method is new in the field of pressed wood board manufacture, and both method and board product are the subjects of pending patents.

Fiber for the fibrous-particle boards is at present mainly prepared either by attrition milling or by explosion fibration. The furnish for granular-particle boards, some of which are designated as "chipboards", has a wide variety of sources and methods of preparation, hammermilling probably being the most common method of reducing particle size. The raw material in the latter connection is usually wood already in a more or less comminuted form, such as planer shavings and sawdust. The furnish for the Long–Bell board, termed crosscut fiber and crosscut flakes, is prepared by a cutting process in which a cutter knife traverses the wood in a direction perpendicular to the grain with the knife-edge alined parallel to the grain and with means provided for cutting fiber or flakes of predetermined length and thickness. Fig. 2 illustrates diagrammatically the basic fiberizing apparatus. Cutting conditions are subject to a considerable degree of control to produce fiber or flakes in a wide range of thickness and length. Examples of crosscut fiber and flake material are shown in Fig. 3.

The advantages of this material are found to be:

(1) A large proportion of the ultimate strength of wood is retained because damage to the botanical wood fiber is minimized in the cutting action. This in turn minimizes the amount of resin binder required to produce board of desirable mechanical properties. For example, flexural bending strengths in excess of 9,000 p.s.i. are possible with phenolic resin binder content of 3 percent or less for boards with specific gravities in the range of 0.95 to 1.0. (2) Energy requirement per ton of material is low, being of the order of fifty horsepower-hours per ton. (3) Wood not usually considered suitable for fiber production, like end trims from kiln-dried lumber, can be uti-

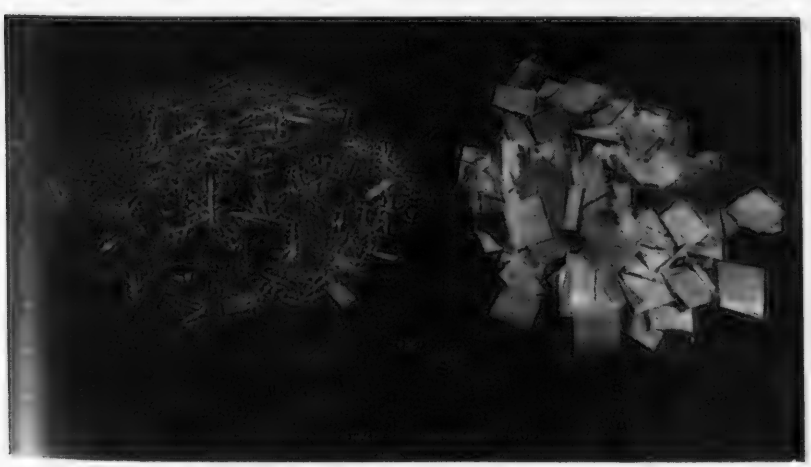

Figure 3.—Long–Bell crosscut fiber (left) and crosscut flakes.

lized. (4) Pressed-wood boards can be produced which retain natural wood appearance and which more nearly partake of the appearance and properties of plywood and lumber than of fiberboard and paperboard.

The other important unit operations of the process, namely, fiber drying, fiber classifying, fiber metering, fiber-resin mixing, mat-forming, and hot-pressing are influenced to varying degrees by the nature of the fiber. In particular, it was found necessary to develop entirely new and special equipment to accomplish the classifying, metering, mixing, and mat-forming steps. Considerable variation in the bulk density of the fiber because of raw materials variation and certain cutting variables posed special difficulties in the metering, mixing, and mat-forming operations which required a great deal of developmental time and expense for their solution.

Description of Products

In common with the other pressed wood manufacturing processes, pressing conditions in the Long–Bell process can be varied within wide limits to afford a wide variety of board densities with a resultant wide range of bending strength, hardness, and other mechanical properties. The kind and amount of resin and other additives incorporated into the product with a simple mixing operation can be used to extensively influence the physical properties of the board. Decorative or appearance values are also determined by these variables as well as by the wood species and fiber- or flake-cutting conditions.

General-Purpose Plain Boards: Plain, smooth-two-side, general-purpose boards, with thicknesses in the range of 1/8-inch to 3/8-inch can be produced with the following approximate range of specifications:

Specific gravity	0.85 to 1.0
Flexural modulus of rupture	4,000 p.s.i. to 9,500 p.s.i.
Flexural modulus of elasticity	700,000 p.s.i. (at 1.0 sp. gr.)
Toughness (work to maximum load)	2.5 to 3.0 In.—lbs. per cu. in.
Water absorption, percent	10 to 16
Linear expansion, percent	0.20 to 0.25

The foregoing figures are obtained by test methods as specified in American Society for Testing Materials, Tentative Methods of Test for Evaluating the Properties of Building Boards, A.S.T.M. Designation: D1037–49T. When comparisons with fibrous-particle boards produced by other processes are made on the basis of equal densities, those crosscut fiber pressed wood boards that have so far been found commercially feasible appear in general to have comparable bending strength and water absorption values, somewhat higher thickness swelling, very high stiffness associated with a comparatively low toughness rating, and probably the lowest linear expansion of any hard-pressed fiberboard. Edge workability is found to be extremely good.

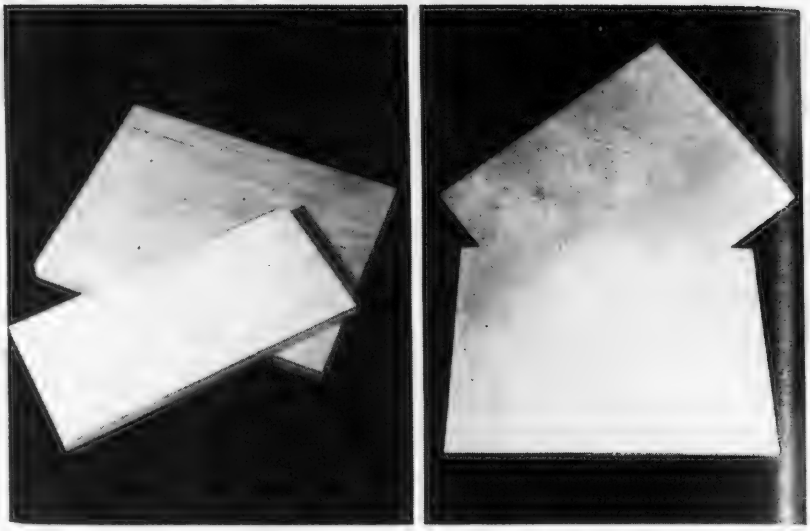

Figure 4.—Five-eighths-inch core board overlaid with 1/40-inch vertical-grain fir veneer (left) and 1/4-inch plain board. The core board has a specific gravity of 0.6 and a flexural modulus of rupture of 2,500 p.s.i.; the plain board has a specific gravity of 0.95 and a flexural modulus of rupture of 5,000 p.s.i.

No items equivalent to the tempered or treated types of boards have advanced beyond the laboratory stage as yet.

Thick Core Boards: Thick boards in the range of 3/8-inch to 3/4-inch thickness and specific gravities of 0.6 to 0.8 have also been developed from crosscut fiber furnish and found to possess properties well suited to this field of application.

Decorative Boards: Two types of crosscut fiber boards in which the appearance or decorative factor is the primary consideration have been placed on the market. One involves a decorative overlay of randomly disposed wood flakes and the other an overlay of thin wood veneers. Both are made in medium densities (0.90 to .95 sp.gr.) predominantly for wall panelling and related applications where the inherent decorative values in the color and grain of various wood species are desired. The surface appearance of the veneered boards is the same as that of plywood. For wall panelling type of application, the veneer is applied to one side only. The surface of veneered hardboard exhibits a much greater dent resistance than do the veneered plywoods.

The flake overlaid boards are essentially a new board product in which the overlay of wood flakes is in effect a layer of randomly disposed small wood veneers. The flakewood boards can be made with one or both faces overlaid. Inasmuch as in almost all applications only one face need perform the decorative function, present manufacture is confined to boards having the flake lamina on one side only.

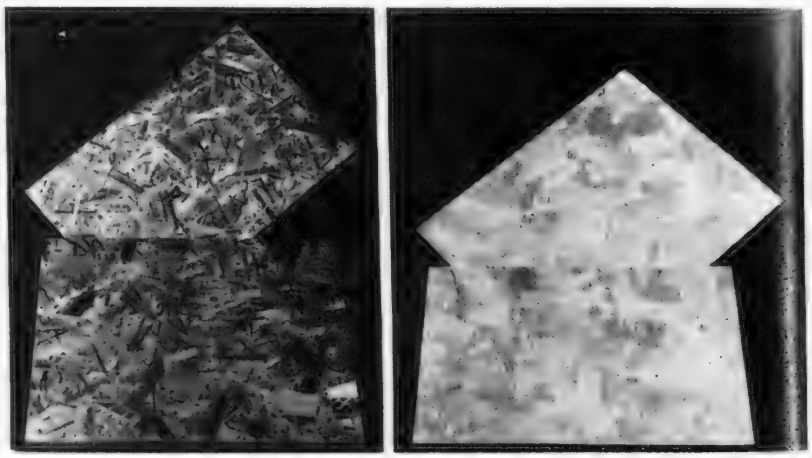

Figure 5.—One-fourth-inch red cedar flake (left) and Douglas fir flake overlaid boards; specific gravity 0.9, flexural modulus of rupture 4,500 p.s.i.

The flake boards possess one especially interesting appearance property. The apparent quantity of light reflected from a wood surface varies considerably according to whether the line of sight is more or less parallel to the wood grain or perpendicular to it. This difference is specially pronounced in certain wood species, for example, ponderosa pine. Because the flakes are randomly disposed in all directions, certain of the flakes stand out brightly in contrast to the others, and these change as the angle of view changes, giving a rather striking irridescent effect to the board.

The photographs of Figs. 4, 5, and 6 show samples of the various forementioned products and give some typical properties.

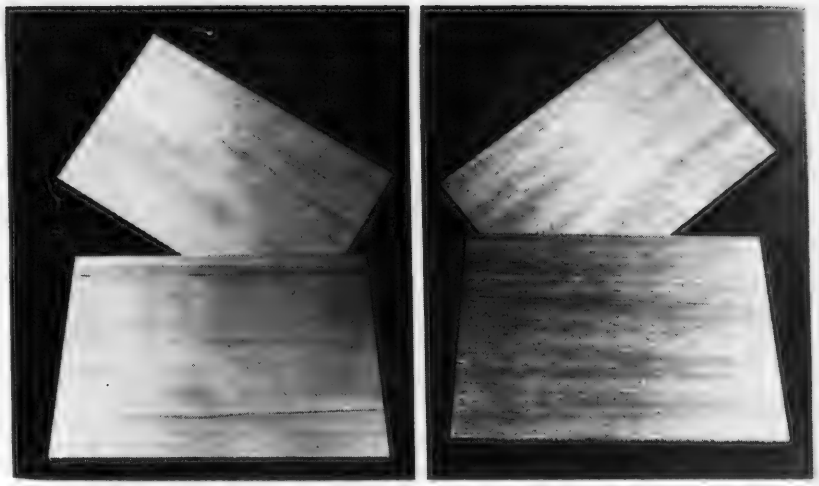

Figure 6.—One-fourth-inch Philippine-mahogany veneered (right) and western-hemlock-veneered boards; specific gravity 0.9, flexural modulus of rupture across face veneer grain 4,500 p.s.i.

The Manufacture of Molded Articles From Resin Bonded Granulated Wood

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and

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A discussion on molding articles from granulated wood combined with resin binders and an evaluation of the effects of variables; such as, pressure, resin content, and wood species on the density, water absorption, and breaking strengths of the molded pieces.

Introduction

TODAY DESPITE an ever-increasing effort to conserve one of our greatest natural resources, wood, new timber growth still lags behind its useful consumption and wanton destruction. One needs only recall the continuing high rate of new building construction and the recent forest fire in California to fully appreciate this condition.

As an outgrowth of the desire for more complete wood utilization, a new industry has come into being; namely, the manufacture of useful, saleable articles molded from a combination of synthetic resin binders and granulated wood. Although the origin of the new industry is only a few short years in the past, its growth has been rapid with much promise for the future.

The advantages of molding articles from granulated wood combined with a resin binder vary according to the amount of required machining and other finishing work eliminated and in the rate of production required to manufacture the molded pieces as compared to other methods of manufacture. The advantages also vary according to the cost and availability of other raw materials, such as, natural wood, when compared with the cost and availability of the granulated wood and its resin binder. In addition, the current trend is toward state laws requiring complete utilization of cut timber and the granulated wood molding process offers another method of complying with such requirements.

Some of the articles now being molded are: salad bowls, croquet balls, bowling balls, shuffle board discs, lazy susans, hamper tops, toilet seats and covers, chair bottoms, chair backs, bases for electric fans, toys, and heels for women's shoes. Perhaps these articles will suggest other molding applications.

The raw materials and procedures

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used in molding articles from resin-bonded granulated wood are as follows:

Wood—The Basic Material

Wood is the basic material used to produce molded articles by the granulated-wood molding process. It constitutes approximately 60 to 90 per cent of the weight of a molded article. The appeal of granulated wood as the main component for molding operations is found in its abundance and low cost.

The species or combination of species of granulated wood which can be used is not a limiting factor. Today, gum, poplar, eastern white pine, southern yellow pine, birch, and maple are widely used either separately or in combinations. The choice of wood used is based on its availability, cost, properties desired in the molded parts, and freight charges.

The particle shape and size of the granulated wood is largely dependent upon the type of product to be molded. Fine, uniform particle-sized, 40- to 100-mesh wood will give smooth, hard surfaces especially suited for painting and other finishing operations. Coarser wood particles 8- to 40-mesh, are used where the detail and finish of the molded articles are not of prime importance.

Once the species and particle size of the granulated wood have been selected, the combination should be maintained. If changes are made, then necessary adjustments must be made to compensate for any differences in moldability and in the end properties of the molded articles.

Where sufficient wood scrap; such as veneer lathe trim, sawdust, chips, etc., are nearby the molder may process his own granulated wood by grinding it in hogs or attrition mills, screening, and drying. In some localities granulated wood already processed may be purchased from numerous suppliers.

Resins

Specifically, resin binders are used to bond the individual wood particles together with the aid of heat and pressure, flowing the resin and then fusing the mass into a series of wood particles and resin links in a compression mold.

The resin binders must be capable of furnishing maximum specific strength characteristics, rapid cure, good mold release and, in some instances, chemical and water resistance to the molded articles.

This article deals with molded parts produced in standard compression type molds. The granulated wood and resin binder are compressed in a contained mold. The escape of volatiles therefore, is very slow—requiring that the moisture content of the wood and resin blend be maintained at a low level. For this reason, the binders used are mainly powdered resins.

The powdered resin binders used are classified as follows:

1. The phenol-formaldehyde type resins are most commonly used because they have exceptionally good thermal flow properties and fast cure, and will produce at a low cost molded articles having excellent physical strength properties and water resistance.

2. The urea-formaldehyde type resins are used when the requirements for the properties of the molded articles are not too severe, especially with reference to water resistance and durability. The urea resins are lower in cost and will cure at lower temperatures than the phenolic resins.

3. The melamine-formaldehyde type resins offer exceptional resistance to light, will produce lighter colored moldings, and will produce moldings with physical properties equal to the phenolic resins. Certain melamine resins have a high buffing characteristic which permits scratches and gouges to be removed from the molded articles with ordinary polishing and buffing equipment. Colorants are sometimes blended with granulated wood and melamine resins to produce colored moldings which do not require painting. The resistance to ultraviolet fading of the melamine resins makes them ideal for this purpose.

Bulk Factor

Granulated wood and its resin binder, in a loose form, occupy a larger volume of space than when compressed into a molded article. This is termed the bulk factor of the material and is defined as the ratio of the volume of the loose material to its volume when molded. It is also defined as the ratio of the specific gravity of the molded item to the apparent density of the loose material.

Specific gravity is defined as the ratio of the weight of a given volume in air to the weight of an equal volume in water, the temperature remaining constant.

Apparent density is the weight of a definite volume of the loose material.

One equation will give a value for any one of the above properties, provided the other two are known:

$$\text{Bulk factor} = \frac{\text{specific gravity}}{\text{apparent density}}$$

Bulk factor varies inversely with the apparent density; the higher the apparent density, the lower the bulk factor and vice versa.

The molder desires a low bulk factor because smaller molds and presses are required to handle the material.

Some of the factors influencing bulk factor are: (1) Particle size and shapes of the granulated wood, (2) Species of wood used, (3) Percentage of resin binder to granulated wood used, (4) Moisture content of the granulated wood.

Blending

The purpose of blending is to prepare from granulated wood, resin binder, and any additives; such as, colorants or external lubricants, a homogeneous mixture. The proper blending of the various materials will furnish more uniform density and properties in the molded articles.

While any mixer or blender that will blend the materials into a homogeneous mixture can be used, for optimum mixing, certain characteristics are desirable. The mixer should be easily cleaned and repaired, have sufficient blending capacity to provide an adequate supply of material for loading the molds, be powered sufficiently to handle large blends, and mix rapidly.

Accurate scales of the rapid reading type are needed to weigh out the various components making up a mixer load.

Molds

Good mold design and construction are very important in any molding operation. Proper attention to these factors will result in fewer difficulties during the actual molding operation. Experienced die and mold manufacturers furnish the molder with well-designed and properly constructed molds.

Some of the advantages offered by properly designed and constructed molds are: (1) Smooth surfaces on the molded items, (2) Longer life of the molds, (3) Less tendency for sticking, (4) Fewer finishing problems.

For long mold life, cold rolled or hardened tool steel is recommended. Softer metals may be used in some instances but they may become pitted or dented through continuous usage and high pressures.

It is also recommended that the surfaces of the molds be chrome plated to facilitate removal of the moldings from the molds and reduce sticking.

Molds are most frequently heated by steam; but electrical resistance heaters are also in use. Some use is made of circulating oil, and superheated water.

Pre-drying

Granulated wood is a hygroscopic material and its moisture content will fluctuate with changes in the relative humidity of the surrounding air.

Because the granulated wood and its resin binder are molded in contained or closed molds which restrict the escape of volatiles, it is necessary that the moisture content of wood and resin blend be controlled to approximately 5 to 8 per cent. Some moisture is necessary to help

promote resin flow, but excessive moisture increases cure time—undercured moldings may rupture when pressure is released or have inferior physical properties—and promotes excessive flow, causing sticking.

When moisture variations cause molding difficulties, it is advisable to dry the wood itself, or the blend of wood and resin, the latter under controlled conditions of time and temperature, prior to molding. If this cannot be done, cure times should be increased sufficiently to dissipate the excess volatiles. Moisture content should be checked at regular intervals by use of a moisture meter.

Cure Time

During the cure time, heat is applied simultaneously with pressure. The heat serves two purposes in granulated wood molding operations: (1) Heat softens the resin converting it into a fluid state. In this form the resin flows throughout the mass of granulated wood. (2) Heat cures the fluid resin by the process of condensation into an insoluble, infusible, thermoset binder.

To obtain molded articles having satisfactory properties the resin binder must have high initial flow so that maximum binding of the wood particles will be obtained.

The resin binder must be fast curing so that the maximum production rate will be achieved, thereby keeping the unit cost of the article at a minimum.

Cure time is largely dependent upon the maximum thickness of the moldings. The thicker the cross section, the longer the cure time. The minimum cure time is that time at which pressure can be released and intact moldings obtained. This time may or may not be the optimum cure time. The optimum cure time is that required to produce molded articles having satisfactory end properties and this must be determined by testing of the pieces.

For phenolic type binders, temperatures of 300 to 350 degrees F. are used; for ureas and melamines, 280 to 300 degrees F. Temperatures should be controlled within ± 10 degrees.

Insufficient heat increases the cure time thereby reducing production and increasing unit cost.

Excessive heat may excessively darken the molded articles, wastes fuel, and may cause over-curing of the thinner sections of the articles resulting in small blisters or bubbles which will cause pieces to be rejected or add substantially to the finishing operation.

Pressure

Pressure is applied to the granulated wood and resin binder confined in a mold cavity for two reasons: (1) To compress the bulky material to the desired volume or to the shape of the mold, and (2) To promote resin flow by reducing the volume of the voids between the wood particles so that the fluid resin seeks out the voids and coats the wood particles. Reducing the volume of the voids affords required binder coverage with a minimum quantity of resin.

There are no established rules for determining pressures. The optimum pressure must be determined for each application; it is that pressure necessary to produce moldings having satisfactory end properties. Generally, however, molded articles are pressed within a range of 500 to 1,200 p.s.i.

Once pressure has been established for any molding operation, it must be adhered to very closely if all the moldings are to have equivalent properties. It is the established practice to press to stops and to equip the press with automatic controls to insure uniform pressure and dimensions.

Presses

Hydraulic presses of the accumulator or self-contained types of conventional design are widely used for granulated wood molding operations. However, any type presses which will rapidly and steadily apply uniform pressure are satisfactory. Presses should be (1) Well constructed to withstand the continuous use of high pressure, while permitting application of pressure to the material within the mold cavity in 8 to 12 seconds after loading. (2) Have sufficient daylight between the platens to facilitate the loading and unloading. (3) Adaptable to other molding applications.

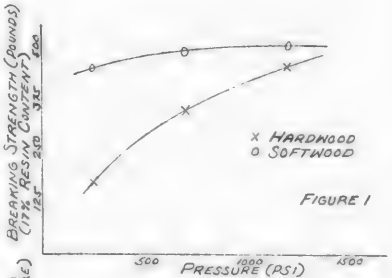
Coloring

Finishing operations add substantially to the total cost of manufacturing. In some instances finishing costs can be reduced by molding colored pieces. This is done by two methods: (1) Adding one or more colorants; such as, dyes or pigments to the blend of wood and resin. To reduce costs where ever possible, only the surfacing material need be colored. In colored moldings the color is found throughout the article or throughout the surfacing material. Therefore, surface scratches and gouges can be easily removed using ordinary polishing equipment. (2) By the selection of the granulated wood according to color. Each species of wood has color all its own and beautiful eye-appealing moldings are made possible by this method.

When molding colored articles, it is necessary that sufficient colorant be used to furnish the required covering power and color intensity. Fine, uniform wood particles should be used at least on the exposed surfaces. Equal pressure must be applied to all areas of the molded part so that color intensity and gloss will be uniform.

While the phenolic and urea-type resin binders may be used in color applications, where highest quality is required, the melamine type is recommended because of its light color, high buffing characteristic, and its resistance to fading and darkening by ultra-violet light.

It should be emphasized that it is not possible to satisfactorily color all molded articles. The adaptability of coloring for any specific application must be determined by the molder.



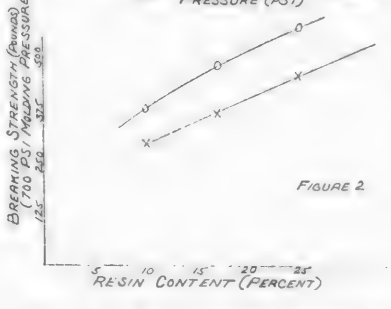
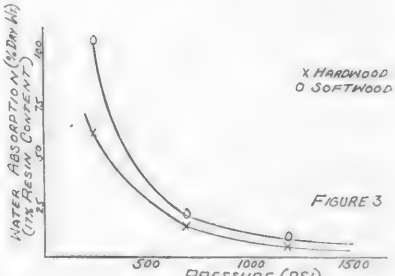


Figure 1.—Effect of molding pressure on strength of molded articles. Figure 2.—Effect of resin content on strength of molded articles.



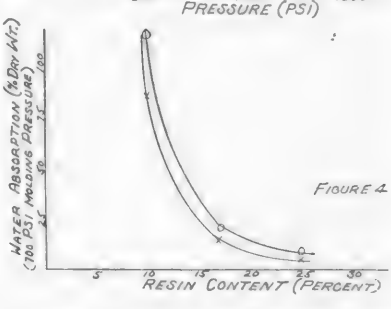


Figure 3.—Effect of molding pressure on water absorption of molded articles. Figure 4.—Effect of resin content on water absorption of molded articles.

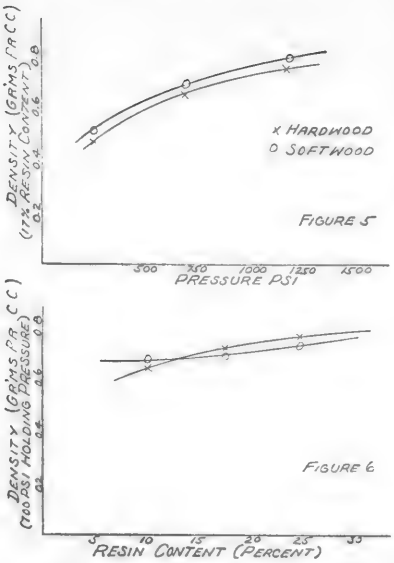


FIGURE 5

FIGURE 6

Figure 5.—Effect of pressure on density of molded articles. Figure 6.—Effect of resin content on density of molded articles.

Evaluation and Quality Control

The purpose of testing molded articles is to determine their properties and to evaluate the influence of variables on these properties. Through adequate evaluation and testing, the necessary wood and resin formulations and molding procedures can be determined. Once established, desired end properties, such as, specific gravity, water absorption, impact strength, breaking strength, et cetera, should be controlled through testing.

The testing methods used need not be too elaborate and involved; in fact, reproducible tests which can be made rapidly and easily are best suited for the average granulated wood molding operation.

The American Society for Testing Materials Standards (ASTM) are approved methods for testing. ASTM methods, or modifications of these methods, were used to conduct the tests discussed in this article and these are suitable for plant testing procedures.

Tests suggested include those for moisture content, specific gravity, water absorption, nail and screw pull resistance, flexural strength, compression strength, tensile strength, and dimensional change.

The references used for these tests are contained in the ASTM Standards, 1949 publication as follows: Evaluating the Properties of Building Boards; ASTM Designation: D1037–49T.

Discussion of Experimental Results

In order to obtain specific end properties in molded articles, an understanding of the effects of individual and combined variables is necessary. The scope of this article is limited to those variables considered of greatest importance. These are: pressure, resin content, and wood species.

Constants Maintained During the Evaluation

A commercial, two-stage, powdered phenolic resin was used as the resin binder because previous work and its wide usage by industry indicated that, as a general purpose binder, the excellent flow and rapid cure charcateristics would produce molded pieces with optimum properties. After blending of the granulated wood and resin binder, the moisture content was 8 per cent. The temperature of the mold surfaces was 350 degrees F. The species of wood used were: (a) 40-mesh birch and (b) 40-mesh eastern white pine. The test specimens were one-fourth inch in thickness and were cured for 5 minutes in a compression type mold.

Effects of Pressure, Resin Content, and Species on Strength

The results of tests depicted in Figures 1 and 2 can be summarized as follows: (1) Increased pressure improves the breaking strength of molded articles made from hardwoods or softwoods. (2) Increased resin content also increases the breaking strength for both hardwoods and softwoods. (3) The breaking strength of products from softwoods is higher than these made from for hardwoods.

Effects of Pressure, Resin Content, and Species on Water Absorption

The results of tests depicted in Figures 3 and 4 can be summarized as follows: (1) Increased pressures improve water resistance for both hardwoods and softwoods. (2) Increased resin content also improves water resistance for both hardwoods and softwoods. (3) The hardwoods are generally more water resistant than the softwoods.

Effects of Pressure, Resin Content, and Species on Density

The results of tests depicted in Figures 5 and 6 can be summarized as follows: (1) Increased pressure increases the density of molded articles made with hardwoods or softwoods. (2) Increased resin content will also slightly increase density, but the effect is minor as compared to the effects of pressure. (3) The softwoods exhibit greater density than the hardwoods with increased pressure. With increased resin content, little difference was observed in density between the softwood and the hardwood used.

Summary

Pressure, resin content, and wood species influence the physical properties of molded articles. Specific physical properties of the molded parts may be obtained by using combinations of these factors. Equivalent properties are obtainable for either hardwoods or softwoods.

Moisture content, and temperature are factors which influence rate of cure and the degree of cure determines the ultimate physical properties of the molded articles.

Extruded Resin-Bonded Wood-Particle Board

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This paper deals with the extrusion method of manufacturing Chipcore. Equipment, quality control, production, and cost are discussed. Chipcore, as the case with any manufactured product, can be made in varying quality. Because of the flexibility of the extrusion method the Chipcore product can be tailored to the application needs. Continuous operation is the guide to a consistent product. In the extrusion method all possible variables are under constant control.

THERE HAS BEEN a great deal of discussion about wood composition products during the past few years. We may attribute this to increased lumber costs, spirited competition, dwindling timber resources, expanding market, and the always existent search for new materials. Fiber, bark, wood fines, sawdust, and wood chips have been used. Molding, pressing, rolling, and extruding are manufacturing methods which have been successfully employed. This paper deals solely with data acquired from the conversion of wood chips to panels by the extrusion process.

American industry is rapidly heading toward the autonomous era. Extrusion is ideally suited to a continuous or automatic operation. As you will note from Figures 1 and 2 the operation is set up on assembly line bases. Frequent use of gravity feeding is employed, however the operators are located on one level so as to eliminate all possible waste motion. The chipcore material is not touched by the operators until after it leaves the glue spreader at the veneering operation.

Under conditions where there is a continuous supply of wood scrap available to the swing-hammer shredder only 2 men are required for the operation of a 48-inch-wide Chipcore extrusion unit. This includes the mixing and veneering operation. The 48-inch unit produces about 9,000 square feet of 1/2-inch core per 24-hours.

Due to the design of the extrusion system the maintenance factor is unbelievably small. The extruder is mechanically driven, all lubrication is fully automatic and continuous, and all parts located at points of wear can be readily replaced.

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Density	.60	.70	.80	.90
Modulus of rupture	1,100	1,900	2,300	3,000
Swelling, length, percent	3.75	2.6	1.9	1.7
Swelling, width, percent	.7	.7	.7	.7
Swelling, thickness, percent	1.1	1.1	1.1	1.1
Water absorption, percent	65	42.5	22.5	10

Av. moisture content after pressing 7 to 10 percent.
Av. glue solids 7 to 9 percent.

Equipment

The equipment required for an extrusion Chipcore plant is as follows:

(A) Chipper (needed when wet waste is used), (B) swing-hammer shredder, (C) continuous drier (when moisture content exceeds 10 percent), (D) tramp-metal separator, (E) storage bin (Composed of screens, oversize-chip return, and chip-removal conveyor), (F) chip weighometer, (G) resin-chip blending mixer; (H) continuous resin-chip blending system (substitutes for F and G items where large volume production exists) (I) extruder, (J) automatic cut-off arrangement, (K) veneering section (including conveyor from extruder to glue spreader, glue spreader, and hot-plate press with loaders) and (L) the conditioning Chamber. (It is frequently found advisable to condition panels for stability reasons by gradual adjustment of moisture and temperature in a hot stack under moderate pressure. Items A, C, K, and L are sometimes not needed).

Density Range

A wide range of densities can be accomplished in Chipcore material by the extrusion process. Densities as low as .3 can be attained in fluted stock whereas, by increasing pressures and percentage of resin solids, densities higher than solid wood may be achieved.

Physical Properties

The following are average figures for physical properties compiled by users and independent laboratories. They involve various types of wood and testing conditions, and therefore should only be considered as relative.

The type of wood or fibrous material used reflects directly on such characteristics as modulus of rupture and dimensional stability. We have obtained excellent results with such woods as oak, cedar, ponderosa pine, poplar, and gum. The degree of particle size segregation is the major assurance of final panel flatness and stability.

Uses

The following are some of the common uses for chipcore: Furniture core stock, wall panels (solid), fluted door core, block flooring, interior decorative panels, novelty cases, interior mouldings, stock panels.

Advantages of Extrusion

Advantages of extruded Chipcore over pressed Chipcore can be listed as follows: (1) Chip orientation. (The chips aline themselves at right angles to the board surface, with better bonding to veneers), (2) extruded Chipcore can be veneered direct from machine without sanding or planing, (3) no edge-trimming is necessary, (4) the density of extruded material is constant thickness is uniform (5) fluted panels can readily be extruded, (6) density can be varied quickly and easily.

Disadvantages of Extrusion

Extruded Chipcore has the same characteristics as natural wood; hence it has many of the same disadvantages. It is weaker in one direction than the other. This disadvantage can be over-

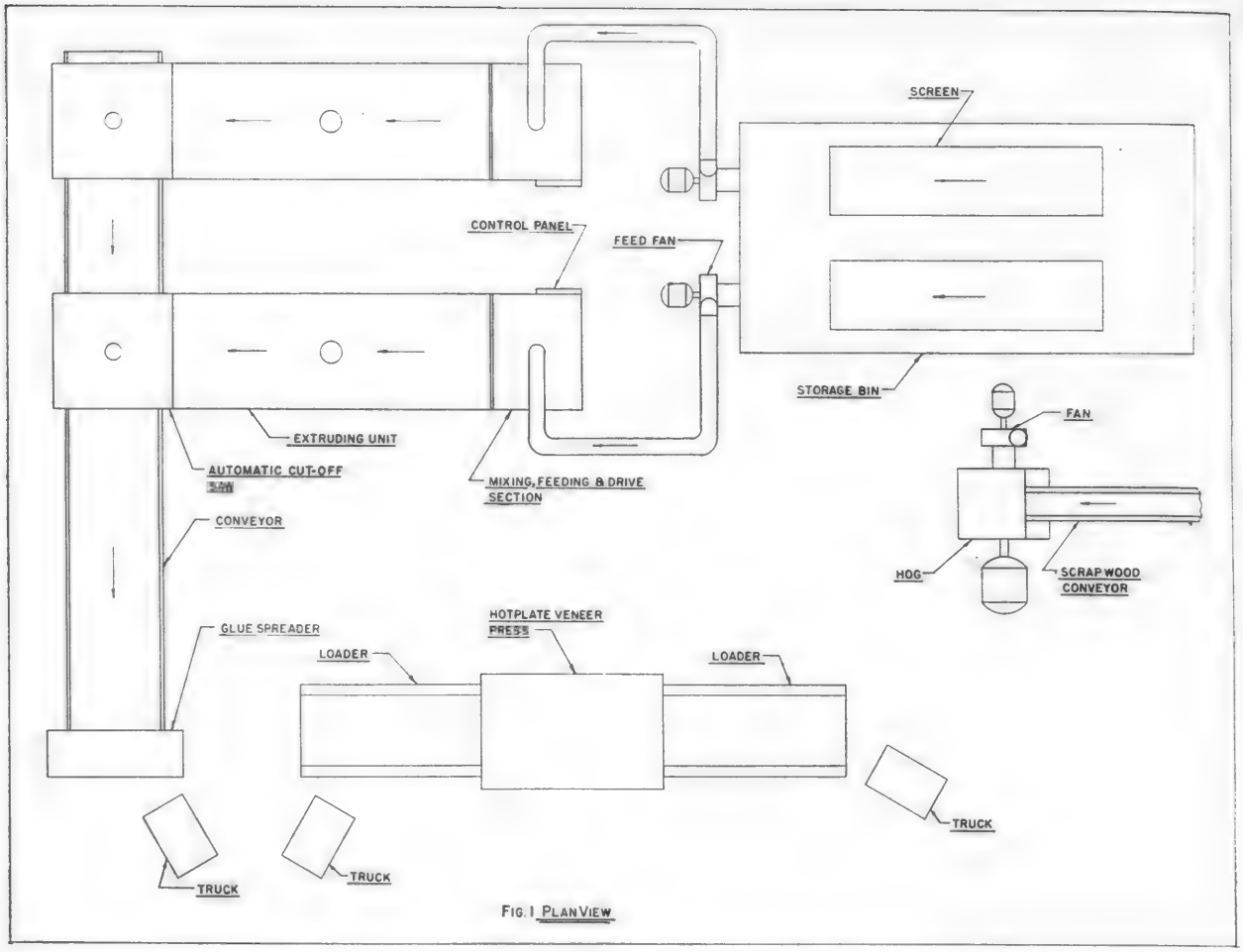

FIG. 1 PLAN VIEW

come by the fabricator if he uses the product as he would lumber core. He, of course, does not have to worry about twists or grain variations when using Chipcore.

Possible Savings

Distinct savings can be brought about by the use of fluted material. For example in a door core of 1⅜ inches in thickness with flutes ¾ inch in diameter on 1 inch centers a saving of 30 percent on weight, and all materials will be realized.

Cost Breakdown

The cost will vary with local conditions, and quality of core made. Veneer crossbands (1/20 inch) can be calculated at roughly $35.00 per thousand (both sides). These cost figures show that Chipcore has a very definite and immediate position in many fields. We feel that any wood working plant having a daily quantity of 10 tons or more of wood waste should very seriously consider it as a potential profit making raw material—not as a boiler fuel.

General operating expense[1]			Cost per 1000
Steam (400 × .40 × 24 × 250)	$ 960		
Electricity (100 KW × 24 × .01 × 250)	6,000		
Maintenance	3,000		
		$ 9,960	$ 4.43
Materials cost			
Wood chips or particles 2,250,000 × 2 × 5 / 2,000	11,250		
Resin mix 2,250,000 × .030	67,500	78,750	35.00
Labor			
Machine operator –3 × 1.50 × 8 × 250	9,000	9,000	4.00
Depreciation at 10 percent		9,000	4.00
Total manufacturing cost per year		$106,710	
Manufacturing cost per 1,000 sq. ft.			$47.13

[1]Costs are based as follows: Equipment cost (subject to change without notice), $90,000; wood chips or particles, $5.00 per 2,000 pounds; resin (62 percent solids), 9½ cents per pound delivered; catalyst, 10 cents per pound delivered; machine operator, $1.50 per hour; annual production of ½-inch board, 2,250,000.

Other Considerations

The extrusion unit produces up to 24 lineal inches per minute, hence production is dependent upon the width and number of extruders. As shown in Figure 1, multiple extruders can be set up. Two extruders still require only 2 operators per shift. Due to the small amount of man power required this system is ideally suited to "round the clock" operation.

The flexibility of the extrusion system is surprising. The same unit can produce solid panels from ⅜-inch to 1¼-inches, and fluted panels from ¾-inch to 4½-inches in thickness. Length and width can be varied at random. Density can be changed while the unit is actually operating.

All extruders are equipped with ample control equipment for making the quality material needed by each particular manufacturer. Therefore, the quality of the material will be determined by preparation of chips, kind and amount of bonding agent, and the control which the operator exercises over the equipment.

At the moment the field of extrusion in the manufacture of resin bonded wood particle material has been

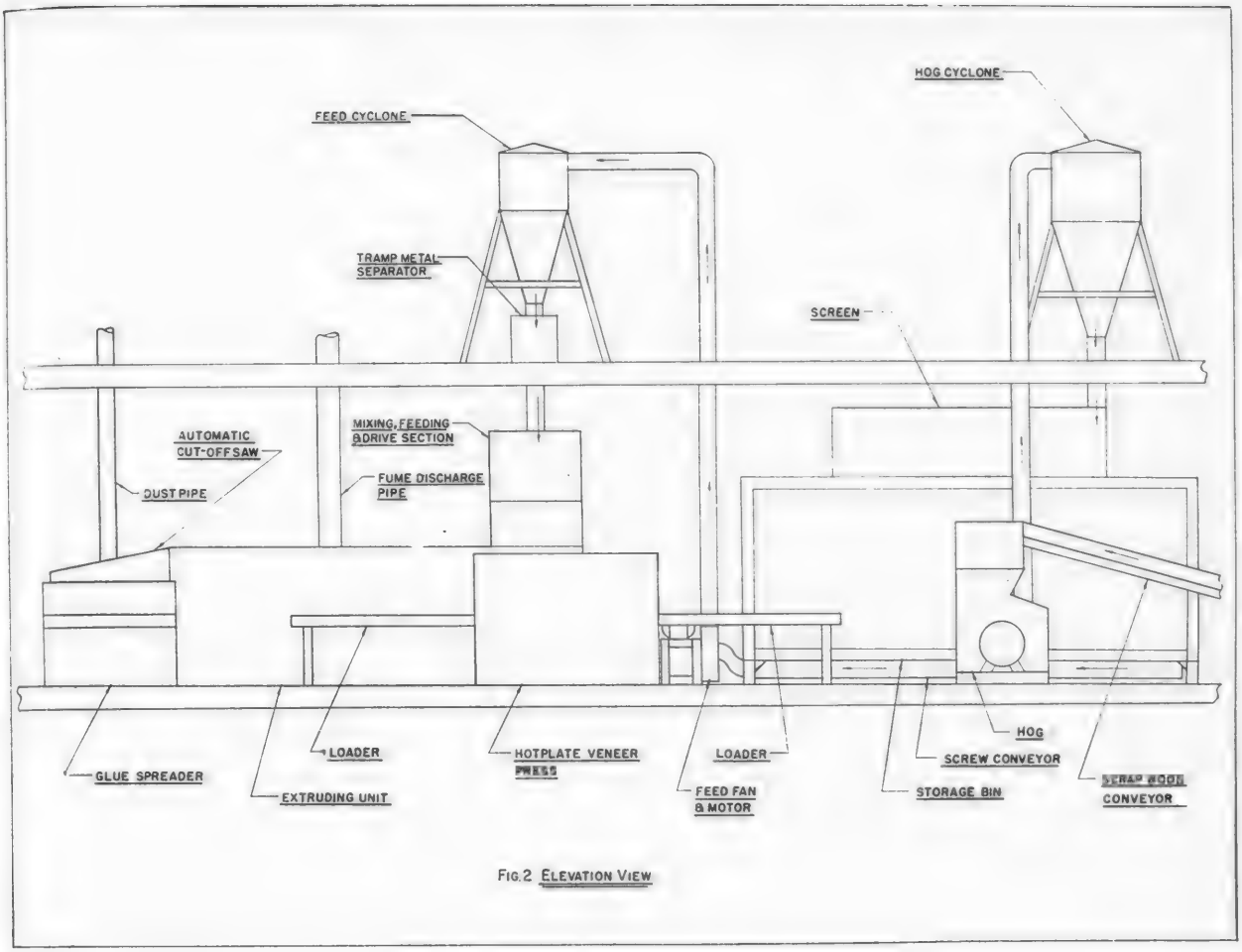

FIG.2 ELEVATION VIEW

touched upon very lightly. It is our belief that the future holds a promise of accomplishments which presently are unknown. Most work has been on flat solid or fluted material but it is certain that further achievements are in the offing in the field of extruded irregular shapes.

The extrusion process lends itself to an in plant operation more readily than the press method. One extruder will use the waste from the average woodworking establishment. Therefore, the producer does not have the problem of obtaining an outside supply of waste. The initial investment is in the range of the purchasing power of the plant which has waste available for a single extruder installation. In our opinion extruding equipment will become increasingly popular in the future because of its versatility and low initial investment outlay.

Subject: Wood Machining

Chairman: L. A. Patronsky

Recorder: Russell C. Deckert

Development Work on Wood Planers

JAY C. PETTER

Buss Machine Works, Holland, Michigan

The wood planer is one of the most frequently used machines in the woodworking industry. It is expected to remove large quantities of material efficiently and produce high quality work. In this paper the author presents research data on the effects of machine design and tool maintenance on the efficiency and quality of work produced by modern wood surfacers.

SEVERAL YEARS AGO one of the wood journals conducted a survey among sectors of the woodworking industry and disclosed some very interesting information regarding the extent of the use of various types of woodworking machinery.[1]

The survey revealed that the saw was the most universally used tool and was in productive use 74.4 percent of a given work period. The next most commonly used tools were planers. They were in use 74.3 percent of the time. Since this survey a great many plants throughout the United States have installed rough mill conveyorized operations and, no doubt, today the percentage of use of the wood-working planer has increased over this earlier survey. Many of you who have encountered production stoppages because of planer shut-downs are fully aware of the flow of material which is controlled by the machine. Down time of a planer usually means the immediate stoppage of a great deal of production.

At the time when the rough mill lay-outs were instituted throughout the country, the woodworking planer was taken from an individual hand fed operation to convevorized production. This meant that the planers had to function many times, without operator in attendance. Feed rates at which planers were normally run years ago (25 to 35 feet per minute) were stepped up to exceed 100 feet per minute. These greatly increased feed rates resulted in considerably more production than had formerly been believed possible.

[1] Wood and Wood Products. 1951. Use of Woodworking Machinery.

ABOUT THE AUTHOR: PETTER, JAY C. Speaker, Session III, Wood Machining, "Development Work on Wood Planers" . . . Vice-President of Buss Machine Works, Holland, Michigan . . . He is sales manager, and does work in research engineering and new products development . . . He received his BS in mechanical engineering from the University of Michigan . . . He is a member of the American Society of Mechanical Engineers, A.S.T.E. and the FPRS.

Research on Power Requirement

These rapidly changing conditions made it apparent that that factual information was needed on the effects of rpms, fast feed rates and knife wear on the power requirements and the life of the machine. Therefore a research program at the University of Michigan was sponsored by the Buss Machine Works to determine the various factors affecting power requirements when planing wood under production conditions.

The planer used for these power studies was a Buss Model 4L, 30-inch wedge-bed machine, having four driven feed rolls. The wearing surfaces were chrome plated, not only for long wear but to cut down frictional resistance. A 15 horse power, 3,600 rpm, 40 degree motor was mounted on the cutterhead arbor; cutting circle 5–3/16 inches, four-knife head, 25 degree cutting angle.

The data presented are based on net horse power to the cutterhead, net power being the horse power consumed by the cutterhead to plane the lumber. Net power equals gross power minus tare power minus electrical losses. Power data were recorded by an Esterline–Angus Model A. W. Wattmeter. A General Radio Strobotac was used to measure the speed of the cutterhead.

The scope of the study was so large that the number of species studied was limited in order to explore the many factors, other than wood species affecting cutterhead power. The tests results are valid only for the species studied.

The tests were made under production conditions for speeds, feeds and depths of cut with every effort being made to control the many variables that enter into the planing of wood. Test specimens used were clear cutting, kiln dried on a very mild schedule to approximately 8 percent moisture content. Before the specimens were planed to thickness for the tests, they were faced on one side on a hand-fed jointer in order to get one flat reference surface. The knives were sharpened and lightly jointed for each test.

Effect of Width of Cut: The effect of width of cut on power requirements was determined for hard maple. The stock was run through the planer at a feed rate of 46 feet per minute with 1/16 inch depth of cut and varying widths of stock. The tests showed that any increase in width resulted in a proportionate increase in power. For example, if the width were doubled, the power consumed would also be doubled. (See Fig. 1) Other species would show variations of this condition, but in general it may be assumed that for any stock the power requirements would increase proportionally to the width.

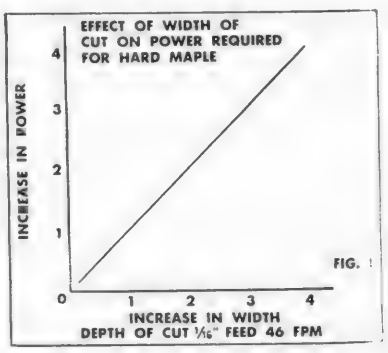

FIG. 1

The power requirements for planing wide core stock would vary vastly from the power requirements of the

same planer where pieces of random width were planed with multiple feeding. The feed motor would have to be larger for planing panel stock as resistance to feeding becomes larger with wider stock.

Effect of Depth of Cut: The most frequent cause of motor overloading is excessive depth of cut, which usually "chokes up" the planer. This can be avoided if the planer operator will

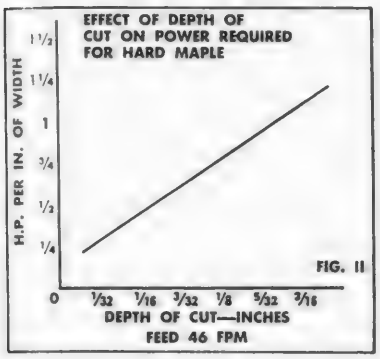

FIG. II

set aside oversize stock, stock with bull heads, and saw runout. Then after the load is run, reset the planer for the greater thickness and run the oversize stock. This, of course, is not possible in conveyorized operations so the planers are protected from jams with safety devices such as limit rolls, shear pins in the feed works and relay heaters. In hand fed operations too often the planer operator feeds the oversize stock into the planer taking a very heavy cut for which the motor horse power is not adequate. This results in the stock jamming the planer.

In further tests the effects of depth of cut on power consumption was determined for hard maple. The stock was run through the planer at a feed rate of 46 feet per minute and a head speed of 3,600 rpm; each run with various depths of cut of 1/64, 1/32, 1/16 and 1/8. The relationship of power to depth of cut is shown in Fig. II. It can be observed from the graph that as the depth of cut increases, a proportionate increase in power results. For example, if the depth of cut is doubled, the power needed to take the increased cut is approximately doubled. The power consumption of course varies with species, moisture content, and specific gravity.

Effect of Grain Direction: The power consumption is greater when the stock is planed against the grain than with the grain, but the difference for most practical purposes is small, and its effect may be ignored. However, the surface quality is greatly affected by the grain direction.

Effect of Feed Rate: In this study we were particularly interested in the power requirements of the planer in relationship to the feed rate of the machine. Tests were run for four species of lumber to determine the power consumption at various feed rates. The stock was run through the planer at feed rates from 22 to 137 feet per minute with depth of cut kept at 1/16 inches. These tests showed that an increase in feed rate increased the power required, although the rise in power is not proportionate to the increase in feed rate. (See Fig. III) For example, if the feed rate is doubled, the power consumption is less than doubled. This seems to be logical as the faster feed results in each knife cutting a thicker chip, therefore, being more efficient.

For example, the increase on basswood at 100 feet per minute is about three times that at 25 feet per minute. This means that the power requirements of the cutterhead motor is increased three-fold while the feed rate is quadrupled.

Tool Maintenance Studied

Effect of Knife Condition: Another important factor influencing power consumption is the condition of the knives. Tests run on planing hard maple using $\frac{1}{16}$-inch depth of cut showed that the power consumption of dull knives at the end of a day's production was about twice as great as the power consumed at the same feed rate and depth of cut when the knives were sharp at the beginning of the day's run. (See Fig. IV) This means that the cutterhead, feed motor, gearing and all working parts were compelled to force the lumber past dull knives. Under those conditions all working parts of the machine and the wearing parts are subjected to undue wear and stresses. Vibration and stresses are also imposed upon the cutterheads and machine frames. As the knives increase in dullness the motors overload, "kick out" and stop the conveyor line and consequently also, production.

As the planer runs considerably more stock in a conveyorized operation than when hand fed, the knives must be ground more often to keep them in good cutting condition. This requires setting up rigorous maintenance programs so that knives are ground with the frequency that is consistent with production and material being cut. When plants set up sound programs of grinding knives, many of the problems described previously disappear and reduce production stoppage, and, at the same time, improve the surface quality of the work.

Our service engineers checking production in plants in various sections of the country, frequently found that loss of production was due to a poor maintenance program in grinding and jointing of the knives. Knives sometimes were ground only once a week even though production might be as high as 20,000 feet per day. As production men realize more and more the importance of maintenance, frequent grinding of knives in production shops will become normal procedure. It has been definitely established that if knives are ground frequently, less time is required to bring them to sharpness than if the knives are permitted to become badly worn and chipped. The time consumed to sharpen knives will be more than paid for by increased production, better work, reduced maintenance cost and longer life of the machine.

Effect of Shaving Choke: One other factor entering into the efficiency of planing machines is the exhaust system. An inadequate exhaust system results in shaving choke, which means the knives recut shavings. This decreases their life between grindings. Shaving choke also overloads the gearing of the feed works besides causing chip printing as the shavings are pressed by the outfeed rolls into the finished wood surfaces.

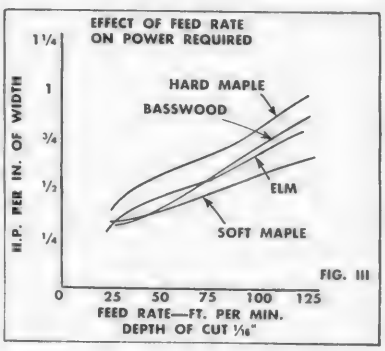

FIG. III

Research on Machine Design Resulted in Higher Quality Work

The importance of the grinding and jointing operation was so thoroughly demonstrated through these studies and through field experiences with conveyorized operations that the Buss Machine Works decided to undertake further research on knife grinding and jointing at the University of Michigan, Wood Technology Laboratory, under the supervision of Professor L. A. Patronsky. Grinding and jointing equipment were subjected to stress conditions normally found in woodworking planers. Analyses by means of strain gages and other precision apparatus resulted in a design change to a one-piece ribbed reinforced heavy grinding rail for precision grinding. This grinding rail was designed to

have adequate rigidity for grinding cemented carbide knives in the planer. Tests on production machines showed deflections in the grinding device to be less than .0001 inch which allows a skilled operator to grind and joint to very close tolerances.

Using this precision grinding equipment, knives were very carefully ground and jointed; tests were then run to determine the number of knife marks that could be observed per inch as the feed rate was increased from 25 to 105 feet per minute. Theoretically, as the feed rate increases (the cutterhead speed remains the same) the number of knife marks per inch decreases. However, as it has probably been the experience of many observers, as the feed rate is increased, sometimes there is no noticeable reduction in apparent knife marks per inch. The reason being that as the feed rate is increased, the minute length variances among the knives have less chance to become obliterated. It can be demonstrated that the short knife in a cutterhead, while it may not show up as a finished mark on the surface of the lumber, will still do 98 percent as much work as the full length knife.[2]

As the feed rate increases, the short knives may make their marks upon the finished surface of the lumber. As knife marks per inch is sometimes used as a gage of good planing, the feed rate can be stepped up and still the minimum number of knife marks per inch will show upon the finished stock, if the knives are ground and jointed within tolerances less than .001 inch. This phenomena can be explained mathematically by its relationship to the care taken in the grinding and jointing operation.[3]

When the knives are ground and jointed to a very close tolerance, more of the knives show up on the finished surface at higher feed rates. This fact is evident in fast-feed molders and in planer matchers. In some mills using fast feed machines, the cutterheads have as many as twenty knives and the feed may run above 400 feet per minute. On a matcher running at a feed rate of 250 feet per minute and having ten knives in the cutterhead, you will get 25 feet per knife per minute ($250 \div 10$). By comparison a planer in a furniture plant on finishing work with four knives in the head and with the feed running at 30 feet per minute will only have a feed rate of $7\frac{1}{2}$ feet per knife per minute ($30 \div 4$), or almost three times the opportunity of the inequality of the projecting knives to wipe out the knife marks on the planer than on the fast feed machine.

The practice in planer-matcher operations is to joint several times during the day and quite a heavy joint is carried (up to 1/32).[4] This can be done as the stock travels at a faster feed rate, and because of the machine's having a much shorter cutterhead. Heavy jointing on these narrow machines does not have the effect that it would have on a wide planer. Heavy jointing is not the solution to good knife work as even with heavy jointing knives may vary from each other if the knives are not ground carefully and cause an increase in planing defects.[5]

Another factor entering into the judgment of good planing is the height of the knife marks left on the finished stock. If the knives are ground and jointed to close tolerances, the height of the knife marks remains about the same as the feed rate is increased until feed rates of over 100 feet per minute are obtained.[3] These figures are all based upon a four-knife head.

However, many woods do not lend themselves to higher feed rates because of the characteristic cutting action of the wood. Various species of woods show increases in planing defects as feed rates are increased. However, the advantage of grinding and jointing with care and accuracy is that the planer can be run at higher feed rates than could normally be obtained with poor grinding accuracy. If the grinding and jointing are done with extreme care and the planer is fed at faster rates than normally used for cabinet work, it is possible to obtain maximum production and the highest quality of planing. The machine must be well-adjusted, have excellent grinding and jointing equipment and the operator must be skilled in the operation, adjustment and maintenance of the machine.

In these days of high labor costs, use of slow feed rates to obtain satis-

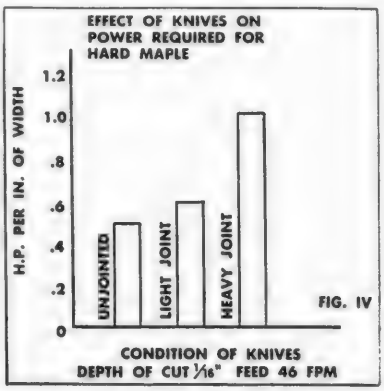

FIG. IV

factory finishes is a cost item which demands consideration not only on the part of the manufacturer but the planer operator. In actual practice with knives ground and jointed to minute accuracy, the number of knife marks per inch will stay about the same regardless of the rate of feed in the range of 25 to 100 feet per minute. It can therefore be strongly stated that fine planing can only be achieved by a careful grinding and jointing operation and that the more the knives vary among themselves, the faster the feed must be set to try to bring all knives into the cut. But if the knives are poorly ground and jointed, the work will become so inferior that before all knives, theoretically, show up in the cut, the operator must reduce the feed and be satisfied to let the one long knife make the finishing cut. It is probably for this reason that many old machines must be operated at low feed rates.[6]

In conclusion, dull knives cause over-stressing of the working parts on the planer and increased wear due to the resistance of the stock as it is fed past the knives. Therefore a rigorous cutting tool maintenance program is imperative. The power increase with dull cutters could be a large factor when all the machines in a plant are considered. Also, the quality work may be poor and productivity seriously reduced.

[2] Chaffe, J. B. 1948. Aspects of Sticker Knife Cuts. Cosgrove's April 1948, 36–38.

[3] Petter, J. C. 1951. Knife Marks on Wood. Buss Machine Works.

[4] Petter, J. C. 1935. Better Planing. West Coast Lumberman. Vol. 62, No. 3.

[5] Davis, E. M. 1952. Further Experiments in the Planing of Hardwoods.

[6] Gray, R. F. Knife Marks per Inch. Forest Products Research Society, California Section, Fall Meeting, 1952.

Machining Tests of Wood With the Molder

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U. S. Department of Agriculture
and
HAROLD NELSON
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This report concerns the effect of certain machining factors on quality of wood finish and on power consumed in operating a modern 6-inch molder. The machining factors include feed rate and cutterhead speed in different combinations, number of knife cuts per inch, cutting angles, knife materials, and moisture content of the test material. The five principal hardwoods and the three principal softwoods were studied. The results are of value in improving molder operation.

Introduction

EARLY IN 1953 the Forest Products Laboratory entered into a cooperative agreement with the Ekstrom–Carlson Company to make certain machining tests on wood with a 6-inch molder furnished by the company. This report covers the test work and findings of this cooperative job.

The purpose of the tests was to determine the effect of such factors as cutting angles, feed rates, and cutterhead speeds on the quality of finish and on power consumption. Although only one make of molder was used, it is believed that the findings would be applicable to other makes operated under the same conditions.

Either the pure research approach or the applied research approach may be followed in a job of this sort. The former is typically a more intensive study of a smaller amount of material involving more precise controls and measurement than are commercially feasible. Usually too it is a long range job aimed at discovering underlying principles that may or may not have immediate application. The applied research approach promised to yield more immediately useful information. It was, therefore, decided on as the more suitable approaach in this cooperative undertaking.

Scope of Report

Most of the work reported here deals with the series of 33 runs outlined in table 1. The factors involved in this series are feed rate, cutterhead speed, cutting angle, type of knife, and moisture content of the wood. Each run consisted of 50 test samples of each of 5 hardwoods and 3 softwoods at 6 percent moisture content plus 50 samples of each of 4 softwoods at 20 percent moisture content or a total of 550 samples. In round figures, 24,000 cuts were made on 3,000 samples. Two other series of 8 and 6 runs were made, dealing respectively with depth of cut and number of knife cuts per inch. The effect of these factors on quality of finish and power consumption was determined in all runs.

This research obviously did not exhaust the subject of molder operation by any means. To do so would require several man-years of work. Some of the factors mentioned above could well be explored further. Some other important factors, such as rate of dulling of different knife materials and size of cutting circles, were not examined. This report, therefore, should be considered merely as a contribution to our general knowledge of molder operation.

Testing Machine

Tests were made with the cooperatot's No. 466 high-speed molder, a modern 6-inch machine weighing roughly 10,000 pounds. It was equipped with a variable feed of from 25 to 225 feet per minute. Five cutterhead speeds were available: 3,600, 4,800, 5,400, 6,000, and 7,200 revolutions per minute. Figure 1 shows the machine with hoods and exhaust pipes removed for better visibility of working parts. Each of the four cutterheads has its own motor, which can be run independently, making it possible to measure the power required for any one motor or any combination of motors. Actually, the top head (fig. 2) was the only 1 of the 4 used in the tests. Consequently, the power requirement figures in this report apply only to that motor in combination with the feed works motor.

Test Material

The five hardwoods tested were yellow birch, red gum, hard maple, white oak, and yellow poplar. These five comprise 75 percent of all hardwoods cut.

The three softwoods tested are Douglas-fir, ponderosa pine, and southern yellow pine.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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Table 1.—PRINCIPAL SERIES OF RUNS MADE IN THIS STUDY[1]

Type of knife	Feed rate F.p.m.	Cutterhead speed R.p.m.	Cutting angles[2] 0°	10°	20°	30°	40°
High-speed steel	60	3,600	X	X	X	X	X
	80	4,800	-	-	X	X	
	90	5,400	X	X	X	X	X
	100	6,000			X	X	
	120	7,200	X	X	X	X	X
Carbide	60	3,600	-	X	X	X	X
	80	4,800	-	-	X	X	
	90	5,400		-	X	X	X
	100	6,000		-	X	X	
	120	7,200	-	-	X	X	X

[1] The 5 hardwoods were tested at 6 percent moisture content only. The 3 softwoods were tested at both 6 percent and 20 percent.
[2] "X" indicates at which angles runs were made.

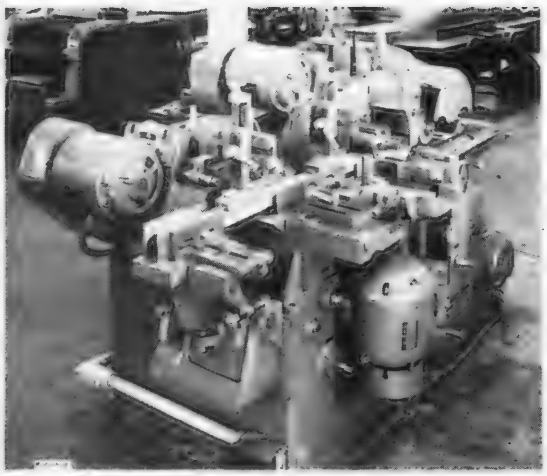

Figure 1.—Molder used in machining tests (left).

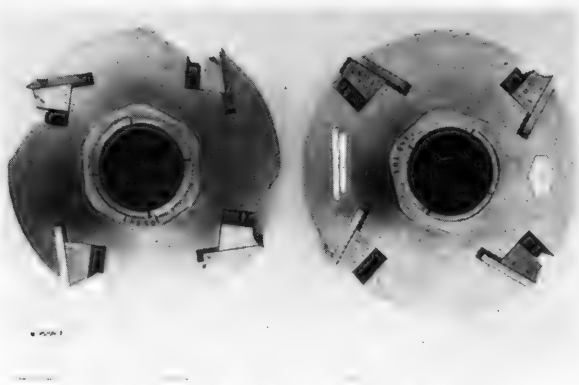

Figure 2.—The two cutterheads used in the tests: left, designed with a 40° cutting angle; right, designed with a 20° cutting angle.

Fifty boards from each species were selected at random to insure normal range in variants within the test material itself. Such variants include density, number of rings per inch, angle between growth rings and surface, and characteristic grain irregularities. After being dried as required, each of the 50 boards was cut into several clear test samples 4 inches wide by 3 feet long (1 board-foot), which were numbered and conditioned to the required moisture content. In this way, six complete sets of test samples were made. Each set consisted of 1 piece from each of the 50 boards in each species at 6 percent moisture content, plus one piece from each of the 50 boards of each softwood at 20 percent, or a total of 550 samples per set. In the course of the series of runs outlined in table 1, all 6 sets were used up. The character of the wood often varies considerably at different points in a given board but, to the extent shown above, the different sets were matched material. The samples as prepared may be considered typical commercial top-grade lumber.

Test Procedure

All tests were made with straight knives in order to eliminate the pattern factor. After grinding, the knives were jointed in the head to get uniform sharpness as nearly as was practical, and to insure that each knife did its share of the cutting. The amount of jointing was just enough to bring all knives to the same cutting circle. This usually left a scarcely perceptible land for the full length of each knife. Where repeated jointing operations produce a relatively wide land, the quality of the finish is of course affected. In this case, however, the land was altogether too narrow to be a factor in itself.

The high-speed steel knives were ground and/or jointed after about every 15 to 30 minutes of continuous work, depending on the feed rate. Although some slight dulling begins quite soon, intervals between sharpenings were much shorter than in commercial practice. Any dulling that took place in this short time is not believed to be significant.

Carbide knives were sharpened only when changed from one cutting angle to another. At those times, light jointing was necessary to get all four knives into the same cutting circle. The intervals between sharpenings were about five times as long as for the steel knives.

As usually understood, the term "cutting angle" refers to the angle between a radial line on the end of the cutterhead and the cutting side of the knife. The cutting angle may be modified by the design of the head. The cutterhead in figure 2, right, for instance, is designed with a 20° cutting angle and the one in figure 2, left, with a 40° cutting angle. In most knives, the cutting edge is beveled in only one direction at an angle of 40° to 45°. Sometimes, however, knives are beveled in two directions, which offers another means of modifying the cutting angle. In figure 2 the knives of the cutterhead at the left have two bevels, the original one and a second bevel or "back bevel" of 20°. The one shown is a 40° head, but the 20° back bevel reduces the actual cutting angle to 20°. These same knives in the 20° head, (fig. 2, right), would produce a 0° cutting angle. Similarly, knives with a 10° back bevel would produce a 10° cutting angle in the 20° head and a 30° cutting angle in the 40° head. The different cutting angles employed in this study were obtained by the use of these two heads using knives with 0°, 10°, and 20° of back bevel.

After the grinding and jointing at the start, the machine was adjusted to the desired feed rate and cutterhead speed. In one series of runs, number of knife marks per inch was the variable under consideration. A constant cutterhead speed was employed, and the feed rate was changed to change the number of knife cuts. In all other runs, the feed rates and cutterhead speeds were so combined as to give 20 knife cuts per inch. Except in one series of runs where depth of cut was the variable under consideration, a uniform cut of 1/16 inch was maintained by means of a steel gage. Seven or eight runs were usually made with one set of samples before they became too thin for further use. Since no two samples are exactly the same in all respects, there are definite advantages in making a series of related tests with one set of test samples.

All pieces of a given species were run through the molder consecutively, the order of species being random. Most samples of the size used have at least some slight degree of cross grain at some point. This was taken into account by feeding the samples so that the knives cut with the grain on half the cross-grained samples and against the grain on the other half.

Promptly after machining, the test samples were carefully examined, one by one, for machining defects and the results recorded on prepared forms. The defects under consideration were raised grain, fuzzy grain, chipped grain, and chip marks. The forms showed which of these defects, if any, were present in any given test sample. They also showed whether any given defect, when present, occurred in a slight, medium, or advanced degree. All this will be explained more fully under the next heading Evaluation of Results.

Power consumption data were obtained by using a wattmeter recording in kilowatt-hours. Because the test samples were only 3 feet long, all 50 samples of each species were run end to end. This made a continuous record for 150 lineal feet per species. Preliminary tests showed that for accuracy and ease of interpretation, this was better than running 50 samples separately with breaks between.

Figure 3 is a tracing of original wattmeter records of power consumed

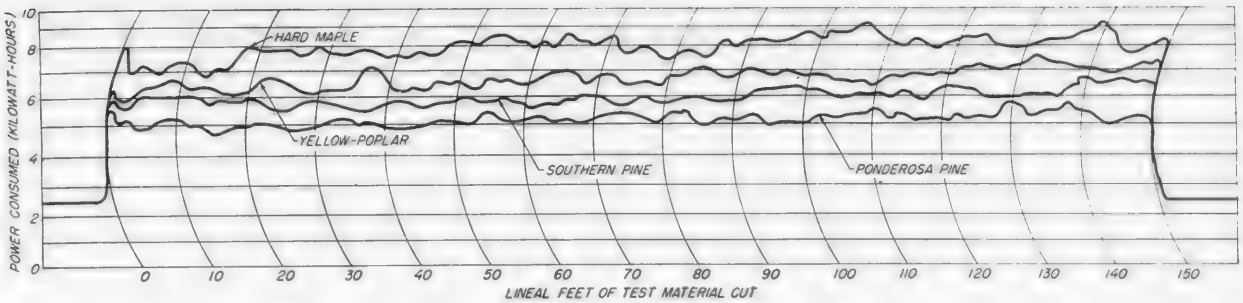

Figure 3.—Recording wattmeter record of power required to machine 150 lineal feet each of four species in the molder. These runs were made under the following conditions: feed, 120 feet per minute, cutterhead speed, 7,200 revolutions per minute; knives, high-speed steel; cutting angle, 20°; moisture content of test material, 6 percent; depth of cut, 1/16 inch.

in molding. In figure 3, however, four species are shown together for comparative purposes rather than singly as in the original charts. Of the eight species tested, figure 3 shows the one using the most power, maple; the one using the least, ponderosa pine; and two intermediate species, yellow-poplar and southern yellow pine.

The low reading at each end of the graph, 2.5, is the power required by the feed and top head motors when idling with no wood passing through the machine. All the central part of the record represents the total power required when actually cutting wood. As would be expected, this varied widely between species. The difference between total power and idling power in any given case represents the power required for cutting and feeding alone.

For any wood shown in figure 3, there are numerous power fluctuations at different points in the chart. These are differences due to character of the 50 individual samples. All such factors as specific gravity, cross grain, and (in some species) number of rings per inch, proportion of summerwood, and angle of rings with reference to the surface effect the power requirement to some extent. Fluctuations like those in figure 3 were found to be typical of random samples in all species tested.

Two types of knife materials were used in these tests, high-speed steel and tungsten carbide. By the Rockwell C scale, the high-speed steel had a hardness of 65.6 and the tungsten carbide 68.5, as compared with 61.7 for carbon steel. Both carbide-tipped knives and solid carbide knives were tried. The tests, however, were not detailed enough to show significant differences. Accordingly, no distinction between these two forms of carbide is attempted here. The carbide knives were supplied by the manufacturer as suitable for the job.

Evaluation of Results

All quality comparisons are based on machining defects. Figures 4, 5, 6, and 7 show the defects referred to, raised grain, fuzzy grain, chipped grain, and chip marks. Sample 4 in each figure illustrates a slight degree of the defect under consideration, sample 3 a medium degree, and sample 2 a serious degree.

These defects were recorded both by frequency of occurrence and by degree. This was done by visual inspection, which raises the question of how accurately different degrees of defects can be determined visually. By using photographs like figures 4, 5, 6, and 7 as yardsticks, defects can be graded accurately enough to show consistent trends and relationships, as will appear later. As far as the incidence of the defects is concerned, there can be little question of ability to decide accurately by visual means whether a given sample has or does not have machining defects. The quality comparisons in this report are based on percent of defect-free pieces. Data on degree of defects are definitely secondary in importance.

Most of the defective pieces are only slightly defective, as will be shown later. For such uses as furniture, fixtures, and interior trim, even slight de-

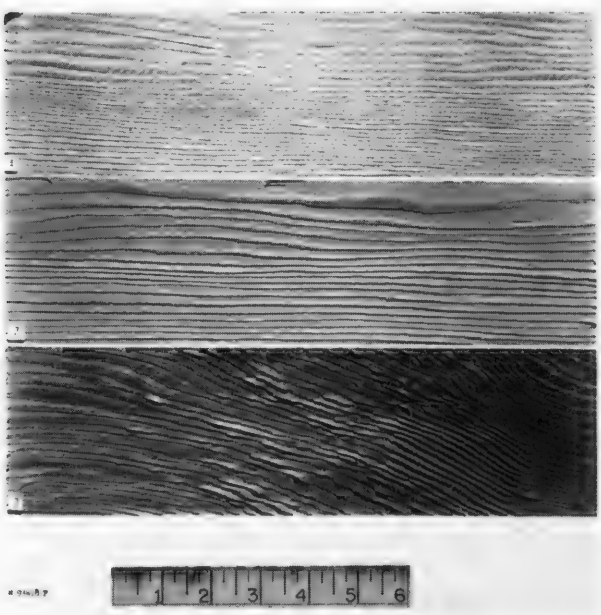

Figure 4.—Different degrees of raised grain.

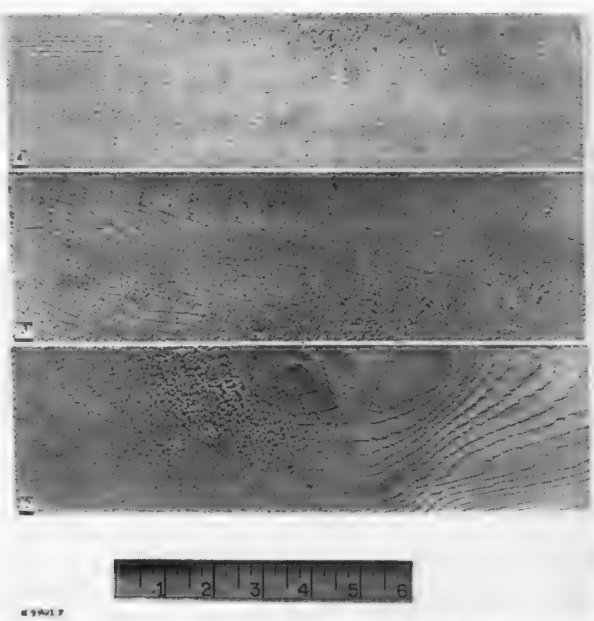

Figure 5.—Different degrees of fuzzy grain.

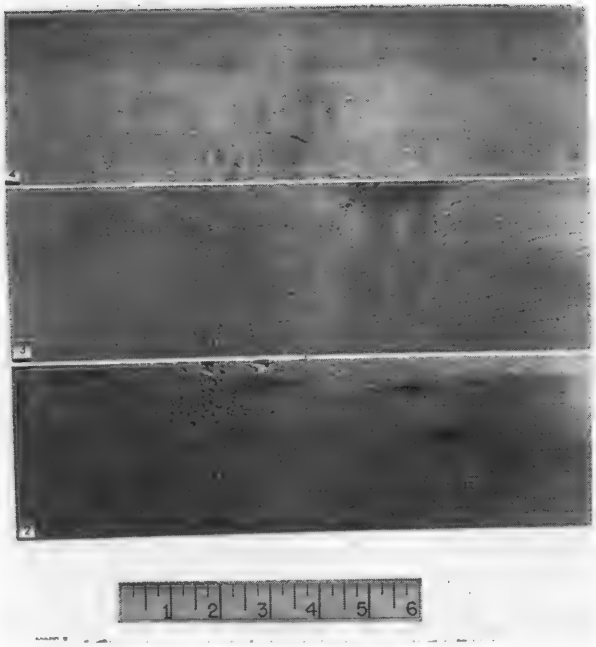

Figure 6.—Different degrees of chipped grain.

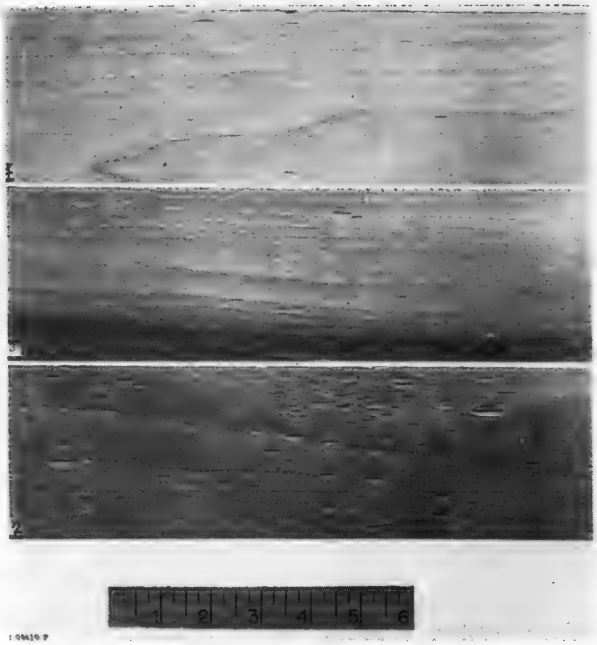

Figure 7.—Different degrees of chip marks.

grees of machining defects are objectionable. In most instances, however, a light sanding would suffice to remove them. From the standpoint of boards and framing, there are two angles to be considered, utility and appearance. Medium and advanced degrees of machining defects would not necessarily reduce the utility much. On the other hand, they definitely hurt the appearance and reduce the saleability, at least in a buyer's market. Good machining properties are therefore an advantage for any wood.

To the extent that the machining defects discussed here affect smoothness of surface, the method used is a rough measure of smoothness. But a defect-free sample of oak will differ in surface smoothness from a defect-free sample of maple because of structural differences. A technically accurate measure of the surface smoothness of wood must take wood structure into account. The method used here, being applied rather than pure research, stops short of this desirable end.

Characteristic Molding Defects

A given defect often varies widely in incidence under different conditions. As many as 70 percent of defective pieces may sometimes be found. In most cases, however, not more than 10 percent of the samples showed any given defect (table 2).

Raised grain is rather a rarity in hardwoods but is common in softwoods, especially at 20 percent moisture content. It is definitely related to the structure of softwoods, and typically the raised portion consists of the relatively hard summerwood (fig. 4). It usually becomes evident as soon as the piece passes through the machine, but pieces that come through smooth may develop some raised grain later if there is a pronounced change in moisture content. Unless too extreme, it may be remedied by sanding. It is more common in lumber planed at high moisture content. As a rule it was much less common in ponderosa pine than in the other two softwoods.

Occasional examples of fuzzy grain (fig. 5) may develop in almost any of the softer woods, depending upon conditions. In this test, however, the only serious instance was in running softwoods at 20 percent using carbide knives. Except in rather extreme cases, this can be remedied by sanding.

All of the woods tested showed more or less chipped grain, as illustrated by maple in figure 6. Only in birch, maple, and Douglas-fir was it at all common. If all lumber were straight grained, no chipped grain would develop in machining, but commercial lumber just doesn't grow that way. Where all the grain slopes in one direction throughout the length of a piece, chipped grain can be avoided by feeding it so that the knives revolve with the grain. But some pieces have grain irregularities of such a nature that the knives necessarily revolve against the grain at one point or another, regardless of which end enters the machine first. This sort of thing is much more typical of birch and maple than of

Table. 2.—OCCURRENCE OF MOLDING DEFECTS IN THE SPECIES STUDIED[1]

Moisture content Percent	Type of knives	Species	Samples having following defects			
			Raised grain Percent	Fuzzy grain Percent	Chipped grain Percent	Chip marks Percent
6	High-speed steel	Birch, yellow	0	0	22	6
6	High-speed steel	Gum, red	0	4	6	1
6	High-speed steel	Maple, hard	0	0	38	3
6	High-speed steel	Oak, white	0	0	8	0
6	High-speed steel	Poplar, yellow	0	1	6	5
6	Carbide	Birch, yellow	2	0	19	11
6	Carbide	Gum, red	1	0	4	6
6	Carbide	Maple, hard	0	0	34	12
6	Carbide	Oak, white	2	0	8	3
6	Carbide	Poplar, yellow	0	1	2	10
6	High-speed steel	Fir, Douglas	46	3	29	11
6	High-speed steel	Pine, ponderosa	20	1	1	0
6	High-speed steel	Pine, southern	38	6	6	1
6	Carbide	Fir, Douglas	69	0	18	32
6	Carbide	Pine, ponderosa	37	0	2	2
6	Carbide	Pine, southern	67	0	4	11
20	High-speed steel	Fir, Douglas	71	1	17	25
20	High-speed steel	Pine, ponderosa	47	0	4	6
20	High-speed steel	Pine, southern	69	0	4	8
20	Carbide	Fir, Douglas	73	60	22	11
20	Carbide	Pine, ponderosa	73	70	1	2
20	Carbide	Pine, southern	78	89	7	8

[1] Based on the mean of the 20° and 30° cutting angles at all 5 feed rate and cutterhead speed combinations.

other hardwoods and is directly reflected in the incidence of chipped grain in those woods. Because chipped grain consists of little depressions below the general level of the surface, it is more difficult to remedy than raised grain or fuzzy grain unless it is extremely shallow.

Chip marks (fig. 7) are shallow depressions in the surface caused by shavings that have clung to the knives instead of passing off in the exhaust as intended. They are affected by sharpness of knives, adequacy of air flow, and also by species characteristics. Douglas-fir, for instance, consistently develops more chip marks than ponderosa pine and southern yellow pine planed under identical conditions. Among hardwoods, red gum and oak were less subject to chip marks than the other three species.

It will be noted that in the lower half of table 2, the figures showing machining defects for a given species often total more than 100 percent. The reason for this apparent discrepancy is that individual test samples sometimes contain defects of two or more types.

Relation Between Defect-Free Pieces and Defective Pieces

As previously stated, the quality comparisons in this report are based on percentage of defect-free pieces. In some instances, the percentages of defect-free pieces may seem unduly low. But it is necessary to keep in mind that most of the defective pieces are only slightly defective. A slight degree of chipped grain covering only a square inch, for instance, is enough to place a sample in the defective category. Table 3 illustrates how this works out in practice. In every instance, the slightly defective pieces exceed the more seriously defective ones usually by a wide margin and, in several instances, the latter are almost negligible. Although the actual figures would change more or less under different operating conditions from those shown in table 3, this same principle holds good under other conditions. Many of the slightly defective pieces would be raised to the defect-free class by the sort of sanding wood normally gets when put to any exacting use.

Comparative Molding Properties

Three of the five hardwoods tested, gum, oak, and yellow-poplar, were about on a par at the top of the hardwood list with 88 percent or more of defect-free pieces. Birch was substantially lower, and maple, the lowest of all, yielded only 61 percent of defect-free pieces or about two-thirds as many as the best hardwoods. Under the machining conditions shown in table 4 both types of knife gave very similar results for hardwoods.

With softwoods at 6 percent, ponderosa pine was much the best, southern yellow pine intermediate, and Douglas-fir the poorest. Parallel results were obtained with the carbide knives, but the percentages of defect-free pieces were substantially lower.

Softwoods at 20 percent fell in the same order as at 6 percent; that is, ponderosa pine, southern pine, and Douglas-fir. The yields of defect-free pieces were much lower, however, and the spread in quality of work between the two types of knife was much wider. As far as softwoods were concerned then, the drier material was definitely better, and high-speed steel knives gave better results than carbide knives with test material at the same moisture content.

Effect of Machining Factors on Quality of Finish

Knife Cuts and Quality of Finish: A series of 6 runs was made at one cutterhead speed, 3,600 revolutions per minute to determine the effect of knife cuts on finish quality. The feed rate was so adjusted in different runs as to give 6, 8, 10, 12, 16, and 20 knife cuts per inch. Depth of cut was constant at $\frac{1}{16}$ inch.

Table 3.—OCCURRENCE OF MOLDING DEFECTS IN VARIOUS DEGREES[1]

Species	Samples cut with high-speed steel knives: Defect-free Percent	Slightly defective Percent	More seriously defective Percent	Samples cut with carbide knives: Defect-free Percent	Slightly defective Percent	More seriously defective Percent
HARDWOODS						
Birch, yellow	73	25	2	72	21	7
Gum, red	84	13	3	90	10	0
Maple, hard	63	25	12	68	21	11
Oak, white	94	5	1	90	9	1
Yellow-poplar	86	13	1	92	8	0
Mean	80.0	16.2	3.8	82.4	13.8	3.8
SOFTWOODS						
Douglas-fir	37	57	6	20	38	34
Pine						
Ponderosa	77	23	0	57	39	7
Southern yellow	69	36	0	28	49	28
Mean	61.0	38.7	2.0	35.0	42.0	23.0

[1]Based on material at 6 percent moisture content, using the mean of all 5 feed-rate and cutterhead-speed combinations with a 20° cutting angle.

Table 4.—COMPARATIVE MOLDING PROPERTIES OF THE WOODS TESTED[1]

Species	Moisture content Percent	Percentage of defect-free pieces: High-speed-steel knives	Carbide knives
Birch, yellow	6	74	73
Gum, red	6	88	89
Maple, hard	6	61	63
Oak, white	6	92	88
Yellow-poplar	6	89	87
Douglas-fir	6	30	17
Pine			
Ponderosa	6	77	60
Southern yellow	6	52	31
Douglas-fir	20	19	3
Pine			
Ponderosa	20	49	9
Southern yellow	20	30	1

[1]Based on the mean of the 20° to 30° cutting angles for all 5 feed rate and cutterhead speed combinations.

Number of knife cuts per inch proved to be perhaps the chief factor affecting quality of work. Considerable variation in the degree to which different species are affected is apparent from figure 8.

The leveling-off tendencies in the upper part of the curves suggest that little further improvement in quality of work could be expected by increasing the number of knife cuts except, perhaps, in maple. In ponderosa pine and oak, for instance, the starting point is considerably higher than for maple and Douglas-fir. The improvement with an increase in number of knife cuts is more rapid, and a leveling-off tendency appears sooner. Oak gave as good results at 10 cuts per inch as maple at 20, and ponderosa pine nearly as good results at 6 cuts as Douglas-fir at 12.

For hardwoods as a group only 22 percent as many defect-free pieces were obtained at 6 knife cuts per inch as at 20. For softwoods as a group, the corresponding percentage was 25.

Data on all eight species tested are shown in table 5.

Feed Rate, Cutterhead Speed, and Quality of Finish: In tests to determine the relation of feed rate and cutterhead speed to quality of finish, 5 different feed rates were combined with 5 different cutterhead speeds to give 20 knife marks per inch in each instance. The combinations were as follows:

Feet per minute	Revolutions per minute
60	3,600
80	4,800
90	5,400
100	6,000
120	7,200

Runs made at each of the above combinations with the two most commonly used cutting angles, 20° and 30° are averaged in table 6.

The general conclusion is that, provided the number of knife cuts per inch is constant, the quality of the work remains constant, regardless of feed rate and cutterhead speed. Other things

Table 5.—NUMBER OF KNIFE CUTS PER INCH AND QUALITY OF FINISH[1]

	Percentage of defect-free pieces					
	Number of knife cuts per inch					
	6	8	10	12	16	20
Birch, yellow	16	40	56	64	72	76
Gum, red	8	36	56	68	80	88
Maple, hard	0	20	32	40	56	64
Oak, white	32	56	64	76	84	88
Yellow-poplar	36	44	56	72	88	92
Mean	18.4	39.2	52.8	64.0	76.0	81.6
Douglas-fir	0	8	24	32	44	48
Pine						
Ponderosa	28	68	76	80	88	88
Southern yellow	20	40	44	56	52	56
Mean	16.0	38.7	48.0	56.0	61.3	64.0

[1]Test made with high-speed steel knives; samples of 6 percent moisture content; cutterhead at 3,600 revolutions per minute; and feed rate adjusted to give knife marks as shown above.

being equal, just as good work can be done with the highest feed rate and cutterhead speed as with the lowest, within the limits of this study, at least. This general conclusion applies to hardwoods at 6 percent moisture content, softwoods at 6 percent, or softwoods at 20 percent. It also applies to both high-speed steel knives and carbide knives. In terms of output this means that it may often be practical to greatly increase the output of a machine without necessarily lowering the quality of finish. Figure 9 shows these relationships graphically.

High-speed Steel Knives, Carbide Knives, and Quality of Finish: Figure 9 also permits a comparison of finish quality results obtained with the high-speed steel and carbide knives.

With hardwoods dried to 6 percent, both types of knife gave closely parallel results. On the average, the high-speed steel knives yielded 81 percent of defect-free pieces as compared with 80 percent for carbide knives.

The spread between these 2 types of knives was wider when it came to machining softwoods at 6 percent moisture content. Fifty-three percent of the pieces produced with high-speed steel knives were defect-free; with carbide knives, 37 percent were defect-free.

At 20 percent moisture content, the softwoods display still wider spread between the quality of work done by high-speed steel and carbide knives. The steel knives produced 31 percent of defect-free pieces and the carbide knives only 5 percent. Under the conditions of these tests 20 percent moisture content for softwoods was far from the optimum for carbide knives.

Certain contrasts between the conditions of these tests and typical commercial practices should be pointed out here. As stated under the heading of Test Procedure, both the high-speed steel knives were sharpened much more frequently than is done in commercial practice. For all practical purposes it could be said that all tests were made with freshly sharpened knives. Under the circumstances this was necessary. It does, however, leave out of account differences in the sharpness life of the two materials. It raises the question, how would results with the two materials compare after continuous operation for 3 or 4 hours? This study does not have the answer. Since the steel dulls more rapidly than carbides, longer runs might well show the carbide knives to better advantage than under the short run conditions of this test.

Table 6.—FEED RATES, CUTTERHEAD SPEEDS, AND QUALITY OF FINISH[1]

				Percentage of defect-free pieces at—				
				Feed-speed combinations of				
Moisture content Percent	Type of wood	Kind of knives	Cutting angle Degrees	60 f.p.m., 3,600 r.p.m.	80 f.p.m., 4,800 r.p.m.	90 f.p.m., 5,400 r.p.m.	100 f.p.m., 6,000 r.p.m.	120 f.p.m., 7,200 r.p.m.
6	Hardwood	High-speed	20	79	82	82	77	80
6	Hardwood	High-speed	30	80	84	82	80	82
6	Hardwood	High-speed	Av.	79.5	83.0	82.0	78.5	81.0
6	Hardwood	Carbide	20	78	85	84	81	84
6	Hardwood	Carbide	30	76	81	78	78	76
6	Hardwood	Carbide	Av.	77.0	83.0	81.0	79.5	80.0
6	Softwood	High-speed	20	56	63	53	63	56
6	Softwood	High-speed	30	51	51	43	45	45
6	Softwood	High-speed	Av.	53.5	57.0	48.0	54.0	50.5
6	Softwood	Carbide	20	36	30	41	31	42
6	Softwood	Carbide	30	35	42	36	43	32
6	Softwood	Carbide	Av	35.5	36.0	38.5	37.0	37.0
20	Softwood	High-speed	20	39	35	38	37	37
20	Softwood	High-speed	30	27	22	24	23	25
20	Softwood	High-speed	Av.	33.0	28.5	31	30.0	31.0
20	Softwood	Carbide	20	2	3	3	3	7
20	Softwood	Carbide	30	7	4	5	6	7
20	Softwood	Carbide	Av.	4.5	3.5	4.0	4.5	7.0

[1]20 knife marks per inch in all cases.

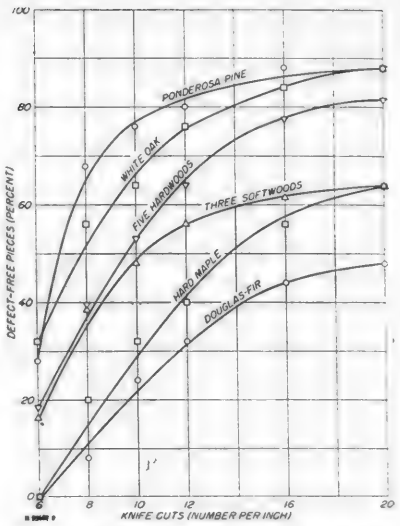

Figure 8.—Effect of number of knife cuts per inch upon quality of finish (high-speed steel knives at 20° cutting angle, 3,600 revolutions per minute, 6 percent moisture content).

Moisture Content and Quality of Finish: Lumber of all species is usually well seasoned for exacting uses. The moisture factor still holds some interest, however, because much lumber, especially in common grades, is dressed at around 20 percent moisture content. Although poor machine work may not affect the utility of common lumber much, it does affect appearance and, to some extent, saleability.

Only the softwoods were tested at two moisture content levels. When cut with high-speed steel knives, the softwood at 6 percent yielded 53 percent of defect-free pieces, as compared with 31 percent for softwoods dried to 20 percent. The most common defect by far at the higher moisture content was raised grain.

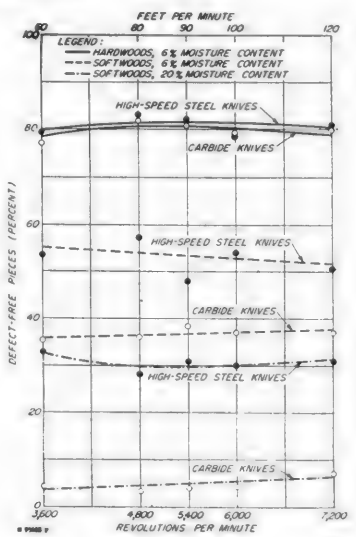

Figure 9.—Effect of different combinations of feed rates and cutterhead speeds on quality of finish. Average of 20° and 30° cutting angles, 20 knife cuts per inch.

The moisture factor had even more influence when carbide knives were used. Thirty-seven percent of the samples were defect-free when machined at 6 percent moisture content, whereas only 5 percent of them were defect-free at 20 percent moisture content. Raised grain and fuzzy grain were much the most common defects at the latter. Table 5 and figure 9 give these data.

Data on the effect of moisture content on the machining of hardwoods are not available from this study. But earlier tests made at 6, 12, and 20 percent moisture content showed 6 percent to give the best results and 20 percent the poorest with hardwoods.

Depth of Cut and Quality of Finish: Four runs were made to determine the effect of depth of cut on finish quality with the following depths of cut: 1/32, 2/32, 3/32, and 4/32 inch. Results are shown in table 7.

Table 7.—DEPTH OF CUT AND QUALITY OF FINISH[1]

Species	Percentage of defect-free pieces at cuts of			
	1/32-inch	2/32-inch	3/32-inch	4/32-inch
Birch, yellow	82	74	68	68
Gum, red	92	82	80	80
Maple, hard	72	62	60	56
Oak, white	96	92	92	88
Yellow-poplar	92	84	84	76
Mean	86.8	78.8	76.8	73.6
Douglas-fir	52	34	36	32
Pine				
Ponderosa	92	78	68	72
Southern yellow	68	62	44	40
Mean	70.4	58.0	49.3	48.0

[1]Test samples machined at 60 feet per minute, 3,600 revolutions per minute, 6 percent moisture content, and 20° cutting angle.

Within the limits covered, the lighter the cut, the fewer defective pieces. In general, the difference between results at 1/32 inch and 2/32 inch was much greater than between any other two successive cuts.

The depth of cut factor affected quality of finish much less on the average for hardwoods than for softwoods. But within each group, certain species differences were evident. In oak, for example, there was only a 9 percent difference between the best cut and the poorest one, as compared with a 28 percent difference in maple. Similarly, in softwoods ponderosa pine quality was much less affected by depth of cut than was southern yellow pine quality. This shows why (with some woods and for some exacting uses) it is often helpful to make a preliminary roughing cut followed by a shallow finishing cut.

Cutting Angles and Quality of Finish: With high-speed steel knives and test samples at 6 percent moisture content, the smaller the cutting angle, the better the results (table 8). This general trend applied to both hardwoods and softwoods. Cutting angles, however, were a much more critical factor for some woods than for others. Maple, for instance, yielded nearly twice as many defect-free pieces at the best cutting angle as at the poorest one. With redgum at the other extreme, there was only a 14 percent difference. Among softwoods at 6 percent, ponderosa pine was not nearly so much affected by cutting angles as either Douglas-fir or southern yellow pine.

Table 8.—CUTTING ANGLES AND QUALITY OF FINISH[1]

Species	Percentage of defect-free pieces cut with—							
	High-speed steel knives at cutting angles of					Carbide knives at cutting angles of		
	0°	10°	20°	30°	40°	20°	30°	40°
HARDWOODS, 6 PERCENT MOISTURE CONTENT								
Birch, yellow	100	81	73	76	59	72	75	53
Gum, red	99	97	84	93	85	90	88	81
Maple, hard	100	69	63	60	51	68	58	46
Oak, white	93	89	94	90	73	96	86	66
Yellow-poplar	97	93	86	93	73	92	82	64
Mean	98	86	80	82	68	82	78	62
SOFTWOODS, 6 PERCENT MOISTURE CONTENT								
Douglas-fir	69	39	37	23	17	20	15	13
Pine								
Ponderosa	90	80	77	77	63	57	64	59
Southern yellow	82	56	64	41	31	28	34	29
Mean	80	58	59	47	37	35	38	34
SOFTWOODS, 20 PERCENT MOISTURE CONTENT								
Douglas-fir	7	19	22	14	21	2	5	5
Pine								
Ponderosa	9	11	62	35	31	8	11	9
Southern yellow	4	7	30	24	17	1	1	1
Mean	7	12	38	24	23	4	6	5

[1]Basis, mean of 3 runs at 60 feet per minute and 3,600 revolutions per minute, 90 feet per minute and 5400 revolutions per minute, and 120 feet per minute and 7,200 revolutions per minute.

Table 9.—CUTTING ANGLES AND SPECIFIC DEFECTS[1]

	Moisture content Percent	Machining defect	Cutting angle				
			0°	10°	20°	30°	40°
			Percent of Pieces with Defect				
Hardwoods	6	Raised grain	0	0	0	0	0
		Fuzzy grain	1	1	2	0	0
		Chipped grain	1	12	16	17	25
		Chip marks	0	1	5	2	15
Softwoods	6	Raised grain	11	39	22	47	43
		Fuzzy grain	0	0	7	0	0
		Chipped grain	0	3	13	11	35
		Chip marks	9	3	2	7	19
Softwoods	20	Raised grain	77	64	52	73	64
		Fuzzy grain	74	61	0	1	2
		Chipped grain	2	3	10	7	14
		Chip marks	0	0	12	14	19

[1]Based on average for the following combinations of feed rates and cutterhead speeds: 60 f.p.m. and 3,600 r.p.m.; 90 f.p.m. and 5,400 r.p.m.; and 120 f.p.m. and 7,200 r.p.m., using high-speed steel knives.

The 0° and 10° angles are little used except in occasional plants that specialize in woods like birch and maple that are quite susceptible to chipped grain. Knives are reported to dull more rapidly at these cutting angles than at larger ones but rate of dulling was not dealt with in this study. Probably the most commonly used cutting angles are 20° and 30°. Under the conditions of these tests the three heavier hardwoods, maple, birch, and oak gave slightly better results with the 20° cutting angle. For gum and poplar on the other hand the 30° angle was definitely better. Ponderosa pine, the lightest of the three softwoods, gave identical results for both of these angles. The 20° angle however proved to be much the better of the two for Douglas-fir and southern pine.

Contrary to experience with hardwoods and with softwoods at 6 percent moisture content, softwoods at 20 percent gave much poorer results at the 0° and 10° cutting angles than at higher ones. This reversal is apparently due to just one thing, a much higher incidence of fuzzy grain at the low angles in the material at 20 percent.

Data on the 0° and 10° cutting angles were not obtained for carbide knives. As far as comparison with high-speed steel knives can be made, however, general trends for the hardwoods at least appear to be parallel.

Table 9 illustrates how some machining defects are much more affected than others by changes in cutting angles. In the hardwoods at 6 percent moisture content, for instance, chipped grain increases from 1-percent incidence at the 0° cutting angle to 25-percent incidence at the 40° angle. With chip marks the same trend is apparent, although it is less marked. With softwoods at 20 percent, a substantial proportion of the pieces show fuzzy grain at the two lower cutting angles. At the three higher angles this defect is missing, or practically so.

Specific Gravity in Relation to Quality of Finish and Power Consumption: The species tested are arranged in order from lightest to heaviest

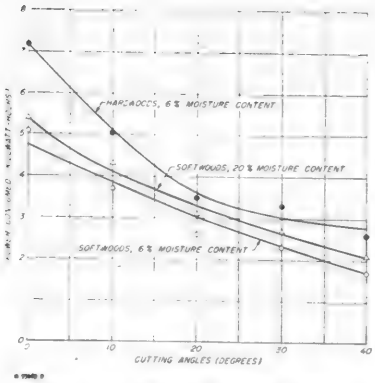

Figure 10.—Effect of cutting angles on power consumed. (High-speed steel knives. All feed rates and cutterhead speeds averaged.)

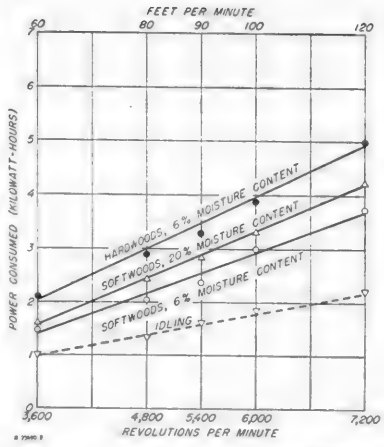

Figure 11.—Effect of different combinations of feed rates and cutterhead speeds on power consumed. (Average of 20° and 30° cutting angles, high-speed steel knives).

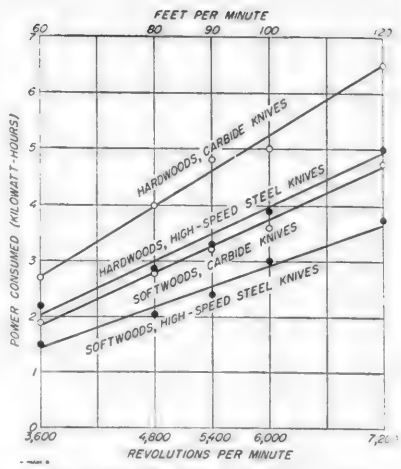

Figure 12.—Effect of different types of knife on power consumed (average of 20° and 30° cutting angles, 6 percent moisture content).

in table 10. Within this range in density at least no relation between specific gravity and quality of machining is apparent. Good machining woods and relatively poor ones can be found toward both extremes of density. Power consumption and density show a more consistent relationship. As a general trend the heavier woods require more power in machining than the lighter ones. But power consumption in machining different woods is not always directly proportioned to their specific gravity. Yellow poplar, for instance, requires more power in machining than some heavier woods, such as red gum and southern yellow pine.

Effect of Machining Factors on Power Consumption

A certain amount of power is needed when the motors are idling, that is, running without any lumber passing through the machine. Additional power is, of course, necessary for cutting and feeding when lumber is actually being machined.

All power-consumption figures in this report, unless otherwise specified, refer to power required for cutting and feeding and not to total power which would include idling power. Under any given set of conditions, cutting and feeding power offer a better criterion of species differences and of the effect of machining factors than does total power.

Table 10.—SPECIFIC GRAVITY IN RELATION TO QUALTY OF FINISH AND POWER CONSUMPTION

Species	Specific gravity of test samples[1]	Defect-free pieces[2] Percent	Power consumed Kw.-hr.
Pine, ponderosa	0.40	77	2.2
Yellow-poplar	.48	89	3.2
Douglas-fir	.50	30	2.3
Gum, red	.52	88	2.8
Pine, southern yellow	.54	52	2.8
Birch, yellow	.63	74	3.3
Oak, white	.65	92	3.5
Maple, hard	.66	61	4.2

[1]Based on weight and volume at test
[2]Based on average of all feed-rate and cutterhead-speed combinations at 20° and 30° and 6 percent moisture content.

Where the machine design or similar problems are involved total power may be what is needed. Kilowatts can be converted to horsepower, if desired, by multiplying by 1.34.

Cutting Angle and Power Consumption: As has already been shown, the better machining results were obtained with the smaller cutting angles. These better results were paid for, to some extent, by greater power consumption. Figure 10 shows that power requirements steadily decreased with increases in the cutting angles. The 0° cutting angle required over twice as much power as the 40° angle. This is equally true of hardwoods at 6 percent moisture content, softwoods at 6 per cent, and softwoods at 20 percent. The three curves parallel each other quite closely, hardwoods taking the most power as would be expected from their higher density, followed by the softwoods at 20 percent and the softwoods at 6 percent, in that order.

Corresponding figures for carbide knives were obtained only at the three higher cutting angles. At these angles the carbide knives took from 27 to 35 percent more power than the steel knives. Aside from differences in power

Table 11.—CUTTING ANGLES AND POWER CONSUMPTION

Species	Moisture content Percent	Power consumption at cutting angle of[1] 0° Kw.-hr.	10° Kw.-hr.	20° Kw.-hr.	30° Kw.-hr.	40° Kw.-hr.	Average Kw.-hr.
HIGH-SPEED STEEL KNIFE							
Maple, hard	6	8.1	5.8	4.4	4.1	3.2	5.3
Oak, white	6	7.4	5.0	3.5	3.5	2.6	4.4
Birch, yellow	6	7.1	5.0	3.5	3.2	2.6	4.3
Yellow-poplar	6	7.0	4.9	3.3	3.1	2.4	4.1
Gum, red	6	6.3	4.5	3.0	2.7	2.1	3.7
Average		7.2	5.0	3.5	3.3	2.6	4.3
Pine, southern yellow	6	5.8	4.2	2.9	2.7	1.8	3.5
Douglas-fir	6	4.9	3.4	2.6	2.1	1.6	2.9
Pine, ponderosa	6	4.7	3.5	2.4	2.1	1.8	2.9
Average		5.1	3.7	2.6	2.3	1.7	3.1
Pine, southern yellow	20	5.5	4.7	3.4	3.1	2.3	3.8
Douglas-fir	20	5.3	4.4	3.0	2.6	2.0	3.5
Pine, ponderosa	20	5.4	3.8	3.0	2.4	1.9	3.1
Average		5.4	4.3	3.1	2.7	2.1	3.5
CARBIDE KNIFE							
Maple, hard	6	---	---	6.0	4.6	4.1	4.9
Oak, white	6	---	---	5.5	3.8	3.6	4.3
Birch, yellow	6	---	---	5.3	3.6	3.7	4.2
Yellow-poplar	6	---	---	5.2	3.5	3.2	4.0
Gum, red	6	---	---	4.7	3.2	3.1	3.7
Average		---	---	5.3	3.7	3.5	4.2
Pine, southern yellow	6	---	---	4.3	2.9	2.4	3.2
Douglas-fir	6	---	---	3.8	2.5	2.2	2.8
Pine, ponderosa	6	---	---	3.6	2.4	2.1	2.7
Average		---	---	3.9	2.6	2.2	2.9
Pine, southern yellow	20	---	---	4.9	3.2	2.9	3.7
Douglas-fir	20	---	---	4.4	2.8	2.6	3.3
Pine, ponderosa	20	---	---	4.1	2.8	2.4	3.1
Average		---	---	4.5	2.9	2.6	3.4

[1]All 5 feed-rate and cutterhead-speed combinations are averaged in figures.

consumption, results for the two types of knives were not dissimilar.

Table 11 gives results for both types of knives in some detail.

Moisture Content and Power Consumption

The following remarks apply only to softwoods because hardwoods were tested at only one moisture content.

With the axe it is certainly easier to chop green wood than dry wood of the same species. With the molder using high-speed steel knives, however, the softwoods at 20 percent took 14 percent more power than the ones at 6 percent, on the average. This difference was fairly consistent at all cutting angles, as shown in figure 10. As far as the moisture content factor is concerned, the carbide knives tell the same story as the steel knives.

Feed Rate, Cutterhead Speed, and Power Consumption: It will be recalled that the combinations of the feed rate and cutterhead speed used in this study had no significant effect on quality of finish. Power requirements, however, increased steadily with increases in feed rate and cutterhead speed. Increasing these rates from 60 feet per minute and 3,600 revolutions per minute to 120 feet per minute and 7,200 revolutions per minute, for instance, increased the power requirements about 2½ times. As shown in figure 11, which applies to high-speed steel knives only, this relationship holds good for hardwoods at 6 percent, softwoods at 6 percent, and softwoods at 20 percent moisture content. Parallel results were obtained when using carbide knives with the same classes of test material. This is shown in table 12 which gives data on both types of knives.

The lowest of the four lines on figure 11 shows the power required for idling. To get the total power requirement this must be added to the power required for cutting and feeding. The data for high-speed steel knives show a slight amount of curvilinearity but do not depart appreciably from the straight lines fitted.

Type of Knife and Power Consumption: The carbide knives ran consistently above the high-speed steel knives in power consumption under the same oprrating conditions. On the average, the carbide knives took 1/3 more power with hardwoods at 6 percent moisture content than the high-speed steel knives required, and ¼ more power with softwoods at 6 percent. This relationship is summarized graphically in figure 12. Table 12 gives more detail including data for softwoods at 20 percent moisture content which tell substantially the same story.

Table 12.—FEED RATES, CUTTERHEAD SPEEDS, AND POWER CONSUMPTION

Type of knife	Cutting angle Degree	Power consumption at feed and speed of— 60 f.p.m. 3,600 r.p.m. Kw.-hr.	80 f.p.m. 4,800 r.p.m. Kw.-hr.	90 f.p.m. 5,400 r.p.m. Kw.-hr.	100 f.p.m. 6,000 r.p.m. Kw.-hr.	120 f.p.m. 7,200 r.p.m. Kw.-hr.	Average Kw.-hr.
HARDWOODS, 6 PERCENT MOISTURE CONTENT							
High-speed steel	20	2.6	3.0	3.3	4.2	4.6	3.5
High-speed steel	30	1.7	2.8	3.3	3.5	5.3	3.3
High-speed steel	Average	2.15	2.9	3.3	3.85	4.95	3.4
Carbide	20	3.2	4.9	5.5	6.4	7.1	5.4
Carbide	30	2.1	3.0	4.1	3.7	5.8	3.7
Carbide	Average	2.65	3.95	4.8	5.05	6.45	4.55
SOFTWOODS, 6 PERCENT MOISTURE CONTENT							
High-speed steel	20	1.8	2.3	2.4	3.1	3.5	2.6
High-speed steel	30	1.1	1.9	2.4	2.9	4.0	2.4
High-speed steel	Average	1.45	2.1	2.4	3.0	3.75	2.5
Carbide	20	2.2	3.5	3.8	4.5	5.5	3.9
Carbide	30	1.5	2.2	2.7	2.6	4.0	2.6
Carbide	Average	1.85	2.85	3.25	3.55	4.75	3.25
SOFTWOODS, 20 PERCENT MOISTURE CONTENT							
High-speed steel	20	1.7	2.7	3.1	3.5	4.5	3.1
High-speed steel	30	1.5	2.2	2.6	3.1	4.0	2.7
High-speed steel	Average	1.6	2.45	2.85	3.3	4.25	2.9
Carbide	20	2.7	4.1	4.4	5.1	6.1	4.5
Carbide	30	2.1	2.5	3.3	3.3	3.7	3.0
Carbide	Average	2.4	3.3	3.85	4.2	4.9	3.75

Some General Suggestions for Improving Molder Work

Faulty work with the molder is often due to dull knives, loose bearings, or lack of proper mechanical adjustment. But it is quite possible to get poor work when all these things are right. It then becomes necessary to look farther for the source of the trouble. In such cases the following suggestions resulting from this study may prove helpful. It is recognized, of course, that, for one reason or another, it will not always be practical to follow them.

(1) If the quality of finish is poor at 8 or 10 knife cuts per inch, adjust the feed rate or cutterhead speed so as to get at least 16 knife cuts. This can be computed from the following formula:

$$\frac{\text{R.p.m. of cutterhead} \times \text{No. of knives in head}}{\text{Feed rate in inches per minute}} = \text{No. of knife cuts per inch}$$

This is the theoretical number of knife cuts per inch. If all knives are cutting, it should agree with the actual number as determined by examining a sample of work. If all knives are not cutting uniformly, a little jointing in the head will be necessary to make them do so.

(2) When the knives are jointed in the head, keep a close watch on the lands, or jointed portion of the edges. The lands form part of the cutting circle and have no clearance. If they are allowed to get too wide as a result of repeated jointing operations, the quality of the finish begins to suffer. When this happens it is time to consider the desirability of regrinding the knives.

(3) Make the finishing cut on the face of the work just as shallow as practical, preferably not more than 1/16 inch. This, of course, applies to plane surfaces, not to patterns. Sometimes a preliminary roughing cut followed by a shallow finishing cut is practical.

(4) If the amount of chipped grain is excessive, reduce the cutting angle of the knives by 10° at least. This produces more scraping action and reduces chipping.

(5) For minimum raised or fuzzy grain, use drier lumber just as far as practical. Twenty percent moisture content is definitely too high for the best results with these defects.

Wood Machining Research With High Speed Motion Pictures

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The cutting action of many woodworking machine tools occurs at such high speed that visual observation of chip formation with the unaided eye is impossible. Recent wood machining research using high-speed motion pictures reveals chip formation phenomena as they actually take place. Other uses for this research tool are suggested as a visual aid to education and to study design features of woodworking machines. High speed motion picture equipment and methods are described.

Introduction

THE WAYS IN WHICH chips are formed by woodworking tools are basically important in developing a science of wood machining. Variability in the structure of wood, both between and within species, complicates research in this field. The influences of knife cutting angles, depths of cut, wood moisture content, density, and configuration of the grain, upon the quality of machined surfaces have been established for many species. Some species react to machining in a manner inconsistent with the general theory. Further studies of chip formation should explain these inconsistencies. The establishment of universally applicable basic laws for wood machining will be of great value to designers and users of woodworking machines and tools. The substantial body of knowledge already available can then be enlarged and used with greater confidence to solve wood machining problems of the day.

Optimum cutting angles and feed speeds have been published, based on the collected experiences of woodworkers as well as the research efforts of scientists. The best results often admit a certain percentage of defective pieces. It is unlikely that the basic variability in the material, wood, will be eliminated, and changes in machinery and tool designs may be necessary to improve the quality of work turned out by some wood cutting processes. Techniques such as down-cutting with the cutting tool and work traveling in the same direction, helical cutterheads, chipbreakers capable of very close and accurate adjustment, and single knife cutterheads operating at high speeds, are hardly new ideas, but their workability for some applications will bear considerably more experimental attention. These investigations should bring forth hitherto untried approaches to the problems.

Current Wood Machining Research

During the past year a large number of wood machining tests have been made, and cutting action has been recorded with high-speed motion pictures. The interest expressed by persons who have viewed these pictures, and that of others who have some knowledge of the application of high speed photography in other fields of research, has prompted the preparation of this paper. It is more in the nature of a progress report than a final report on a completed project.

The experimental work conducted at the College of Forestry has been concentrated on knife cutting problems. Studies have also been made to show the cutting action of circular saws, chain saws, boring tools, and turning operations with hand tools on a patternmaker's lathe. It is hoped to extend this work to show the cutting action of automatic lathes, tenoners, moulders, and other types of woodworking machines. An organized research study has been started on chip formation, with straight knives. Pictures of the other machining operations have been made to study the field of application for high speed motion pictures in wood machining research.

A heavy duty hand feed jointer equipped with a positive, variable-speed, feed mechanism has been used for the knife cutting research. This provides a continuously variable range of feed speeds from 37.5 to 120 feet per minute. The cutting circle dia-

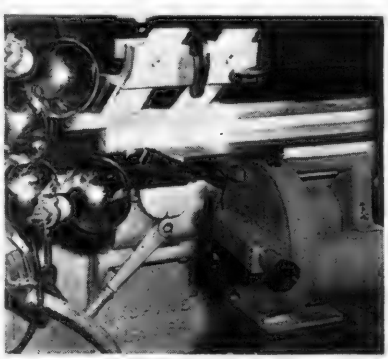

Figure 1.—High-speed motion picture equipment set up to photograph the cutting action of straight knives in a rotating cutterhead.

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[2] Providing special assistance with high speed motion picture methods.

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Figure 2.—Formation of the torn-grain defect in black cherry at six percent moisture content, 30-degree cutting angle, 1/16-inch depth of cut, and 15 knife marks per inch.

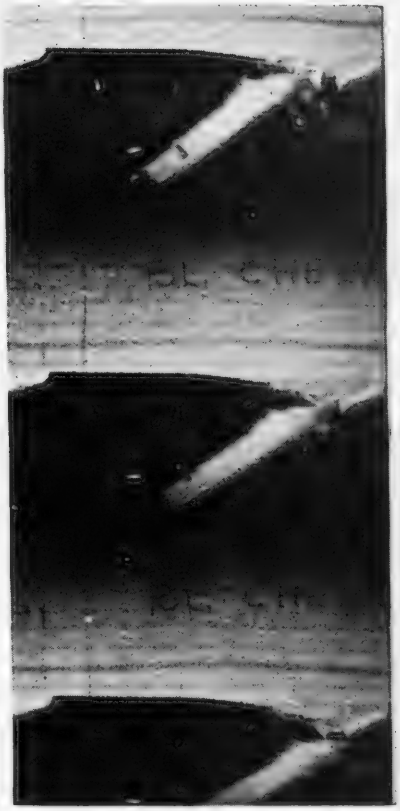

Figure 3.—Splitting type of chip formation without the torn-grain defect, in black cherry at six percent moisture content, 30-degree cutting angle, 5/32-inch depth of cut, and 15 knife marks per inch.

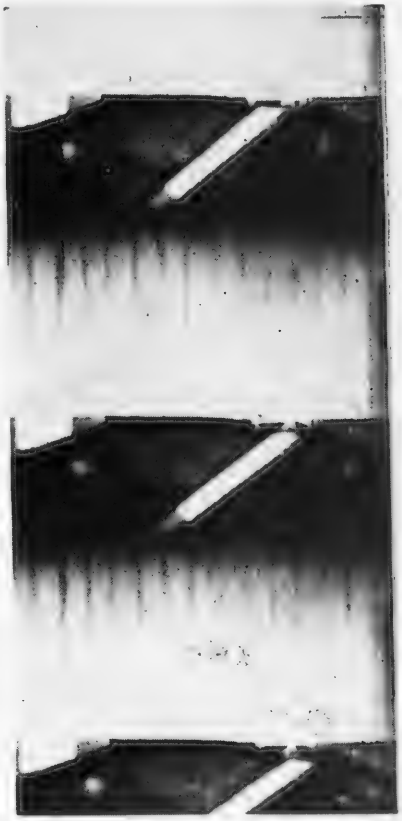

Figure 4.—Chip formation at a 10-degree cutting angle in northern white pine, six percent moisture content, 1/16-inch depth of cut, and 15 knife marks per inch.

meter is 4.5 inches, and there are three 16-inch knives in a cutterhead cylinder operating at 3600 rpm. Markings from 7.5 to 24 knife marks per inch are possible with all knives jointed. Fig. 1 shows a typical test set-up.

High Speed Motion Pictures

High-speed motion picture photography has been used in many fields of research for a number of years. It has found its widest use in the study and analysis of high-speed action in engineering, metallurgy, chemistry, and in such specialized studies as atomic bomb blasts. To our knowledge there has been no published work involving the machining of wood in which high-speed motion picture photography was used.

The principle of high-speed movies is essentially the same as slow-motion photography. The action to be studied is photographed at a greater-than-normal speed and then projected on the screen at the standard rate of 16 pictures per second. The distinction lies in the rate at which the photographs are taken. Slow-motion pictures of athletic events are generally taken at 64 or 128 frames per second. The term "high-speed" usually is applied only to picture-taking speeds exceeding 1,000 frames per second.

The purpose of using high-speed motion pictures in a study such as the machining of wood is to slow down rapid action so that the eye can follow some particular phase of the operation. The extent to which action must be slowed down depends upon the nature and speed of the movement. The speed of the action can be determined mathematically in many cases. Trial exposures at camera speeds based upon these determinations precede final runs. The pictures which were taken in connection with this study required exposure rates ranging from 5,000 up to more than 15,000 frames per second. When these films are projected at 16 frames per second, stretching of time is achieved. Action which lasts one-fifth of a second can be studied critically on the movie screen for as long as 3-minutes. Time has been magnified nearly a thousandfold.

Other high-speed photographic techniques have been used in attempts to "see" the action in the machining of wood. Chief among these is the method reported by Patronsky[1] in which a photograph is taken with high-speed or electronic flash. The flash is emitted from a xenon-filled discharge tube. It is of very high intensity and very short duration, and, when properly synchronized with the action to be studied, effectively "stops" motion. Pictures made in this way are usually clear and sharp, but represent

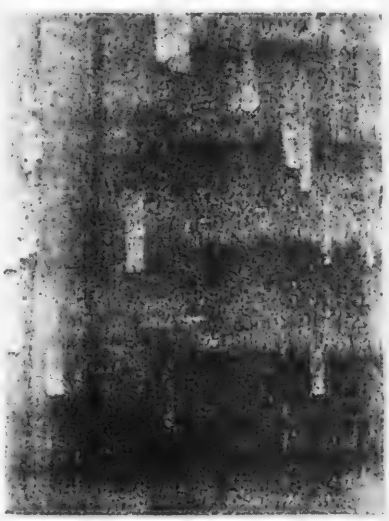

Figure 5.—Chip marks on black cherry machined at six percent moisture content, 30-degree cutting angle, 1/16-inch depth of cut, and 15 knife marks per inch. (2X)

[1] Patronsky, L. A. 1953. Knife Cutting Problems. Jour. F.P.R.S. Vol. III, No. 2, pp. 15–19.

Figure 6.—Formation of a chip mark by a chip which became attached to the knife edge, in machining black cherry at six percent moisture content, 30-degree cutting angle, 5/32-inch depth of cut, and 15 knife marks per inch.

Figure 7.—Formation of a continuous ribbon-like chip, or shaving, in machining northern white pine at 20 percent moisture content, 30-degree cutting angle, 1/16-inch depth of cut, and 10 knife marks per inch.

Figure 8.—Chips formed by the down-cutting principle in northern white pine at six percent moisture content, 30-degree cutting angle, 3/32-inch depth of cut, and hand fed at approximately 12 knife marks per inch.

only one fractional part of a second of action. What happens before this split-second, and after it, is frequently of just as great interest.

High speed motion picture photography satisfies this requirement by providing continuity of action. Some sacrifice must be made, however, if individual frames of the movie film are to be reproduced as they are in this paper. Due to the inherent characteristics of the optics used in high speed motion picture cameras, there is some loss of detail. This loss is not apparent on the movie screen because the individual frames are not viewed for a long enough period, but when enlarged for critical close-up viewing to a size that is suitable for study in a publication, it is obvious. It was felt that the advantages of high-speed motion pictures far outweighed the disadvantages, so it was the method chosen for this series of studies.

Description of Photographic Equipment

The 8-mm. model of the Wollensack Fastax high-speed motion picture camera was used in making these wood-machining studies. Exposure rates as high as 10,000 frames per second can be attained with this camera, and with the use of accessory timing equipment, rates up to 16,000 pictures per second are possible. The special timing equipment was used only in the study of circular saws as the other operations did not require such high speeds.

A high light intensity is necessary, particularly at the higher picture-taking rates. Adequate lighting was provided by focusing water-cooled spotlights and special reflector lamps designed for intermittent use. An exposure meter specially designed for measuring high intensity incident light was used as a guide in determining correct exposures.

Review of Basic Machining Defects

Four types of machining defects directly attributable to conditions surrounding chip formation are: torn grain, fuzzy or woolly grain, chip mark or bruises, and raised grain.[1,2,3,4,5]

[2] Harris, P. 1946. A Handbook of Woodcutting. Department of Scientific and Industrial Research, Forest Products Research Laboratory, Great Britain.

[3] Kivimaa, Eero. 1950. Cutting Force in Woodworking. The State Institute for Technical Research, Helsinki, Finland.

[4] Hyler, John E. Mar. 15, 1950. Woodworking Knife and Cutterhead Applications. Southern Lumberman. Vol. 184, No. 2358, pp. 55–58.

[5] Davis, E. M. 1942. Machining and Related Characteristics of Southern Hardwoods. U.S.D.A. Technical Bulletin No. 824.

Torn grain appears when chips, formed by splitting of the wood along the grain and subsequent breaking across the grain, follow the grain direction and break off below the level of the machined surface. Torn grain is induced by large cutting angles, large depths of cut, high feed speeds, and low moisture content.

Fuzzy grain is formed when the fibers are not cleanly severed at the first portion of each cut. They appear to be stretched or pulled from the surface, or bent over and cut obliquely, leaving filaments of wood projecting above the machined surface. Fuzzy grain is aggravated by small cutting angles, small depths of cut, low feed speeds, dull knives, and high wood moisture content. This defect is less troublesome when a sharp knife is used at peripheral speeds above 5,000 feet per minute.

Chipmarks appear as depressions or bruises in a machined surface. They may be 1/32 inch deep or microscopically shallow. Causes of this defect have not been completely explained; however, low exhaust suction is frequently at fault. The defect may occur when the exhaust suction is adequate. Chips may curl over the tips of

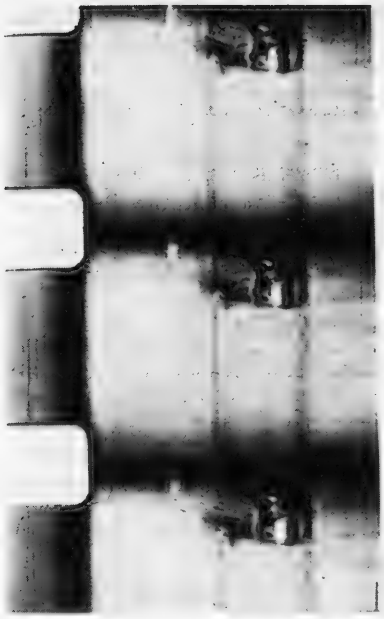

Figure 9.—Cutting action of a ¾-inch brad-point machine bit, when boring black cherry at 4.5 percent moisture content, 600 rpm.

knives and be carried into the succeeding cuts. In some instances groups of wood fibers at the ends of chips become affixed to the knife edges. In machining wood in which the grain slopes out of the piece in the direction of knife movement, partially cut chips may shear parallel to the grain just beyond the knife tip. These chips frequently remain on the knife and cause chipmarks. Chipmarks are some times eliminated by increasing the depth of cut, increasing the feed speed, or reducing the wood moisture content. Density appears to have no consistent influence on this defect. It appears in hardwoods as well as in softwoods.

Raised grain appears in two different forms. In one form the summerwood is raised above the springwood, and in the other the springwood is raised above the summerwood. In the first-mentioned form, separations between summerwood and springwood sometimes occur. The defect is most likely to develop in species in which there is considerable difference in density of summerwood and springwood. The summerwood is impressed into the low density springwood by the pressure of the feed rolls, the pressure bar, or the knives. After machining the summerwood recovers more than the springwood. Cleavage sometimes occurs between the summerwood and springwood as a result of crushing failures in the springwood. The defect is increased by dull knives or knives with wide jointing heels, heavy pressure bar force, low feed speeds, low depths of cut, and flat-grained lumber.

The second form of raised grain, characterized by the summerwood being depressed lower than the springwood, appears in some species at high moisture content. It has been observed in basswood (*Tilia americana L.*) at 20 percent moisture content. It seems to be affected primarily by moisture content and is not a problem when surfacing dry wood. This form of raised grain occurs in species in which springwood and summerwood densities are similar. As mentioned before, some inconsistencies in the relationships between the defects and their causes exist between species and are not satisfactorily explained.

Machining Characteristics Observed in High-Speed Motion Pictures

The relationship between cutting force and cutting angle has been described by Kavimaa.[3] The cutting force exerted by a knife may be considered to have two components. The main cutting force is tangential to the cutting circle.The other component, called the thrust force, acts in a radial direction. Kivimaa has shown that the main cutting force increases as the cutting angle is decreased. The thrust force, directed toward the cutterhead axis at large cutting angles, diminishes as the cutting angle is reduced. It becomes zero at some angle near ten degrees, and becomes negative at cutting angles below ten degrees. These results are helpful in understanding why the grain is less severely torn at small cutting angles than at large ones. It also explains how the wood could be compressed by knives set at small cutting angles, giving rise to fuzzy grain and raised grain defects. Evidence to support these results appears in some of the high-speed motion pictures.

In a series of pictures showing chip formation by jointer knives with 30 degree cutting angles, splitting parallel to the grain followed by failure of the chip in bending was depicted. This type of chip formation leads to the torn grain defect when the grain slopes into the wood in the direction of knife movement. Figure 2 is enlarged from an 8-mm motion picture film. It shows the formation of torn grain in black cherry, (*Prunus serotina* Ehrh.), at six percent moisture content.

The same type of chip formation has been recorded by the high speed camera when machining sugar maple (*Acer saccharum* Marsh.), yellow birch (*Betula lutea* Michx.f.), basswood, black walnut (*Juglans nigra* L.), northern white pine (*Pinus strobus* L.), white ash (*Fraxinus americana* L.), and red oak (*Quercus borealis* Michx.f.). When the grain was parallel to the surface of the wood, or sloped out of the wood in the direction of knife movement, chips were broken off in the area of the wood to be removed by the cuts that followed, and the torn grain defect did not appear.

This type of chip formation, i.e., by splitting parallel to the grain and failure in bending, appears to be normal at cutting angles of 30 degrees, at feed rates producing from 7.5 to 24 knife marks per inch, and in the moisture content range of 6 to 12 percent. These are the conditions covered by the tests made at the College of Forestry at Syracuse. (See Figure 3).

Pictures of northern white pine, sugar maple, yellow birch and basswood machined at a 10 degree cutting angle and six percent moisture content, showed a variation in this type of chip formation that reflected the cutting force changes described by Kivimaa. The chips were split off in a similar way but did not extend as far along the grain. The chips then failed in bending or possibly a combination of bending and compression parallel to the grain. These chips are less likely to cause torn grain than those formed with a 30 degree cutting angle on the knife. This type of chip formation is illustrated in Figure 4.

Several causes of chip marks were recorded by the high speed camera. In machining black cherry on a jointer, chip marks were developed as shown in Figure 5. High speed motion pictures showed that chips were becoming attached to the knife edges and were carried around the cutterhead, where they interfered with the next cut made by the knife. Figure 6, enlarged from frames of the motion picture, shows this phenomenon.

The deflection of small chips into the path of the knives by the leading edge of the infeed table was observed. These chips interfered with cutting and caused chip marks. This implies the need for a thin infeed table lip, or chipbreaker. Undetached chip fragments, which were observed clinging to the surface of the cut, are another possible cause of chip marks. It was noted that greater spacing between the knife tips and the curved surface of the gibs (also called a chipbreaker) would probably allow the chips to clear the infeed table lip more readily.

In machining northern white pine at 20 percent moisture content, with a 30 degree cutting angle on the knives, the chips were formed with little or no splitting. The chips appeared to be severed rather cleanly along the path of the knife tip, in a continuous ribbon. Some splitting occasionally developed in the last stages of chip for-

mation but this was too far from the machined surface to be harmful. A chip of this type is shown in Figure 7.

The down-cutting principle, as seen in high-speed motion pictures, appeared to be very superior to the conventional method of machining, with regard to clean chip removal. No splitting developed when machining northern white pine at six percent moisture content. Chips of northern white pine at six percent moisture content were deflected by the curved surface of the gibs, formed a curled shaving, and passed the lip of the infeed table without interference. (Figure 8 shows this form of cutting action.) Further study of this method of cutting, using other species of wood at a variety of moisture contents, cutting angles, feed speeds, cutterhead speeds, and slopes of grain, is planned.

Frames from a series of pictures of a cut-control saw show that with hand feeding the saw efficiently removes material at a feed speed of 48 feet per minute. Chip formation by a ¾-inch brad point machine bit operating at 600 rpm. is illustrated in Figure 9.

Pictures have been made showing the cutting action of various types of chain saw teeth. The chain saw operates at relatively low speed, compared to the peripheral speed of a sixteen-inch circular saw on a 3,600 rpm. arbor, and is quite easy to photograph. The circular saw, however, presents one of the more difficult subjects to photograph, particularly if there is a large number of teeth on the saw. The peripheral speed of such a saw is 15,000 feet per minute. Photographs of a 16–inch diameter, 48–tooth saw made at exposures of 14,300 frames per second were useful in studying cutting action. Higher exposure rates will provide more satisfactory results for sawing studies at this peripheral speed.

Conclusions

The experience to date at the College of Forestry laboratories shows that chip formation theories can be studied effectively with high-speed motion pictures. Considerable preliminary work to develop information on lighting and exposure problems has been accomplished.

The design of test set-ups to permit observation of cutting action without interfering wih normal cutting conditions is of considerable importance for saws, boring tools, and other tools whose cutting edges are normally hidden from view. In many instances these problems can be worked out but will require more time and effort on the part of the investigator.

Greater magnification will provide clear useful pictures showing the chip in greater detail. Further attention will be given to this feature of the research during the coming year.

The work reveals other possible useful applications for high-speed motion pictures. They have been used in classroom work at the College to explain theories of chip formation. It is believed that a comprehensive study of many woodworking tools illustrating the variety of cutting techniques in use today would be very useful as a visual aid to education. High speed motion pictures can be used to observe the effectiveness of new woodworking machinery design features.

Discussion

James R. Crawner (The B. L. Marble Chair Company): It was stated that chipmarks were sometimes caused by poor blower system. What are the other causes? It appeared in the picture of this defect that it was the same knife each time that was picking up the chip. Is there some condition of the knife that is responsible?

Mr. Hoyle: There are several known causes of chipmarks.

Insufficient exhaust air may permit chips to be carried around the cutterhead in a rotating current of turbulent air. Exhaust systems should draw enough air over the head to prevent trapping of chips in this way.

The chips may become attached to the knife edges mechanically. Small, lightweight chips, produced when taking very light cuts may have wooley or curled fibers which hook them to the knife edges.

In our picture a flat, uncurled chip appears to be attached to the knife edge. Apparently this chip is held to the knife by small fibers, not visible in the picture, or by electro-static forces.

Chipmarks may occur when nicks in a knife tear fibers instead of severing them. These fibers may hook a chip to the edge or may adhere in themselves, causing a small chipmark, or surface fleck.

If chips are firm, curled and long, they will usually fly free of the knives by centrifugal force. There are optimum cutting angles for producing such chips. These angles depend on wood species and moisture content. Generally a reduction in cutting angle will reduce the frequency of chip mark formation.

Small clearance angles may cause compression of chips under the back of the knife causing large defects, whereas use of a larger clearance angle would have avoided compression of the chip and produced only a minor defect or none at all.

Chip weight can be increased by use of higher feed speeds or depths of cut, to throw the chips from the knives.

There are complex factors responsible for this defect which have not been fully explained. The exact cause of a specific occurrence is often hard to determine.

The chips shown in the motion picture do not always cling to the same knife, although they may have done so in the film strip exhibited here. I do not believe a knife condition is responsible in this instance.

Machining Wood With Coated Abrasives

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To secure objective data on the fundamental concepts of machining wood with coated abrasives, The Carborundum Company established a research project at the University of Michigan's Wood Technology Laboratory. The results of some investigations of the factors controllable by the users of abrasive products are presented below. Included are the effects of platen pressure, belt velocity, length of contact area, dressing belts, moisture content and wood species.

Introduction

RELATED TO THE successful application of coated abrasives in the woodworking industry is a working knowledge of the variables which influence the operational characteristics of these materials. An important distinction must be made between those factors which apply to the abrasive and those which apply to its application, as the latter factor is obviously controlled by the user. For this reason much of their use has been primarily based on the knowledge gained through experience.

To add to this information a research project was established by the Carborundum Company, Niagara Falls, New York, at the Wood Technology Laboratory of the University of Michigan, in order to secure objective data on the fundamental concepts of machining wood with coated abrasives. From this research some of the basic relationships of abrasive machining of wood have been developed. It is the purpose of this paper to cite the influence of several factors on the application of coated abrasives when used to machine wood.

Equipment and Methods

A standard horizontal belt sander was modified for use in this study, as shown in Figure 1. The original table has been replaced by a channel iron on which is mounted a hold-down device for securing wood specimens during machining. An oscillating mechanism is connected to this unit to provide reciprocating motion to the work piece. Platen pressures are held constant at any desired level by means of a balance system. The platen is of steel with ground surfaces, and is self-aligning. Belt velocities are accurately controlled over a wide range by use of a continuously variable frequency converter.

Wood specimens for machining each consist of an aggregate of eleven samples randomly selected from the available lumber source. In this way uncontrollable variables tend to average out and give a more representative estimate of the population. Moisture content of the wood is held uniform by means of constant temperature and humidity regulation. During machining, wood specimens are handled in pairs. Each is sanded for a given length of time at the established conditions while the other is weighed to determine the amount of material removed during the previous interim and examined for surface characteristics. Intermittent observations are made during machining to determine surface temperatures. This is accomplished through use of standard Tempilstiks. Power requirements for sanding at various conditions are determined with a recording wattmeter.

Effects of Pressure

This series of studies was designed to reveal the effect of platen pressure on belt life, wood surface temperature, power and surface quality. On the basis of preliminary experiments, all machining in this phase was done parallel to the grain on hard maple in the oven-dry condition. The abrasive belts used were close coat garnet on a paper backing with an animal glue bond. Three grit sizes were included: 80 (1/0), 120 (3/0), and 180 (5/0). Belt velocity remained constant at 5,000 surface feet per minute, while platen pressures varied from 0.4 to 1.6 pounds per square inch. From data showing the weight of material removed from the wood specimens in a given period of time, the average rate of removal in grams per minute was computed for each interval. Plotting these values for each set of conditions over running time obtains the family of curves shown in Figures 2, 3 and 4. It will be noted that the curves shown representing the data for the 5/0 garnet abrasive belt are essentially similar and indicate a smooth increase in the rate of material removal as pres-

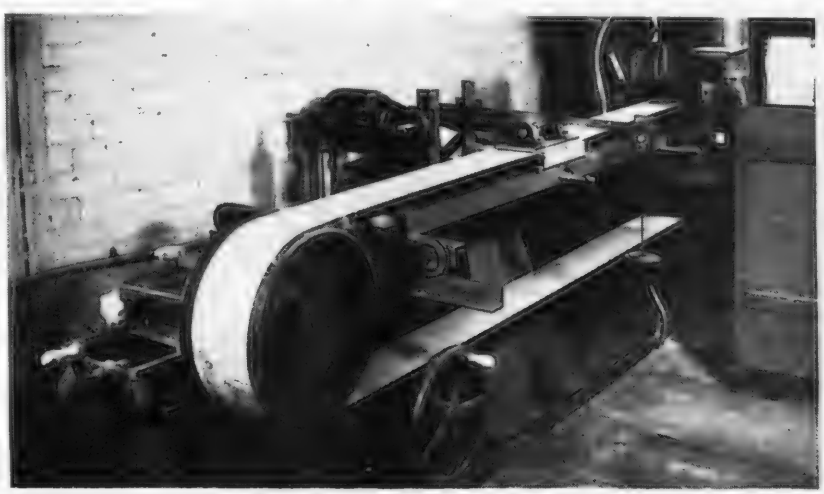

Figure 1.

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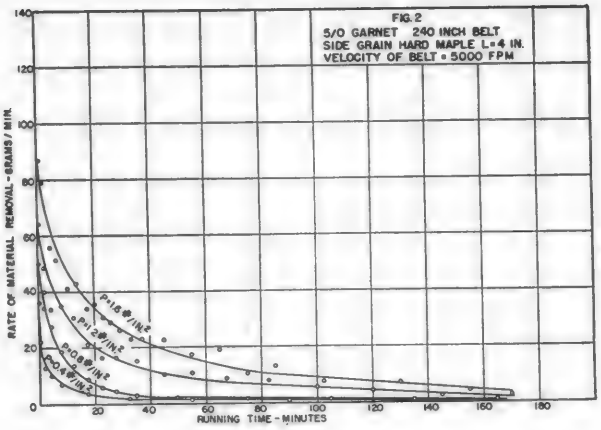
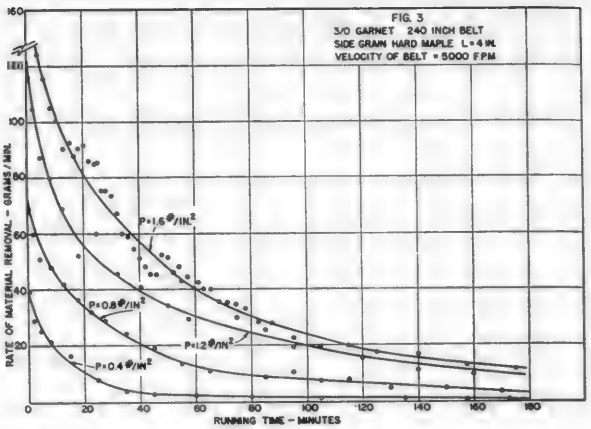




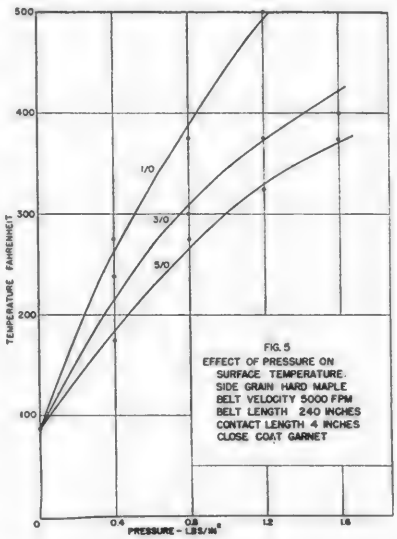
sure is increased. The curves for 3/0 and 1/0 grit sizes tend to follow the same trend at the lower pressures, but deviate considerably as pressure increases. The explanation of the reversal in trend becomes apparent when other recorded data are considered. Figure 5 shows a plot of wood surface temperature with respect to platen pressure for the three grit sizes studied. It will be noted that temperatures during machining extend well into the range where wood substance plasticizes and charring occurs. Observations of belt condition reveal that loading of the abrasive surface with wood fragments is significantly increased as working temperatures rise. Thus it may be concluded that in the case of the coarser grit sizes, an increase in pressure beyond a critical point results in excessive temperatures which in turn contribute to loading of the belt. The loading then prevents the abrasive from cutting at full capacity.

Effect of Belt Velocity

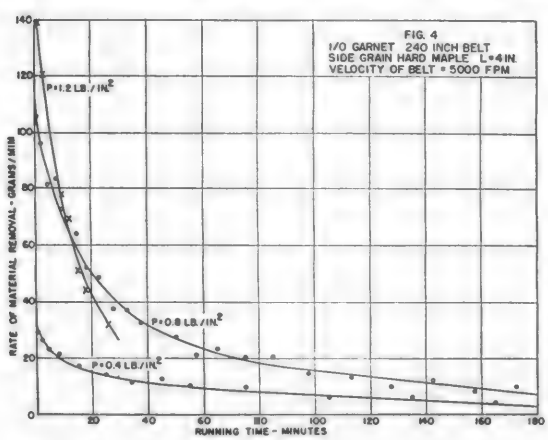
In the woodworking industry garnet is commonly used at belt speeds from 2,500 to 5,000 surface feet per minute, while aluminum oxide is normally found in use at speeds in excess of 4,000 feet per minute. Investigations of the reasons for the selection of these operational ranges shows little factual basis for the practice. In an attempt to determine the validity of current field practice, a study of the behavior of the two abrasive materials was made. Using grit size 120 (3/0) with a platen pressure of 0.8 pounds per square inch, belts of aluminum oxide and garnet were used at velocities ranging from 2,340 to 10,000 surface feet per minute.

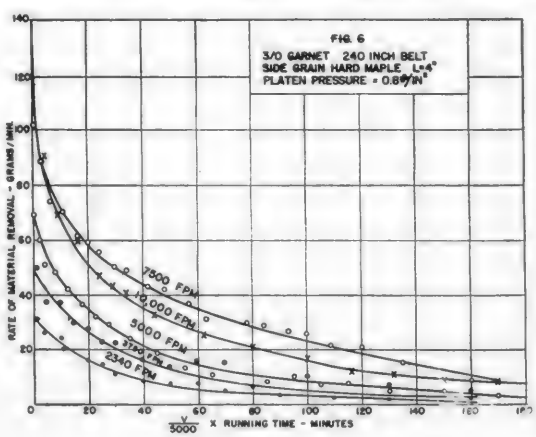
In order to compare directly the results of machining at these various speeds, it is necessary to first resolve the data to a common level. As the velocity of the belt is increased, the distance the belt travels in contact with the wood surface in a given time is proportionately increased. Here, the running time data for the belts was adjusted by the factor of $\frac{V}{5{,}000}$ where V = the velocity of the belt considered. The adjusted data are plotted in Figures 6 and 7. It can be seen that the general pattern developed in the pressure study is again present. The rate of material removal tends to increase as speed increases, as would be expected. However, a critical speed is reached where this trend reverses. As can be seen in Figure 8, excessive working temperatures are encountered at high speeds, causing rapid loading of the abrasive surface.

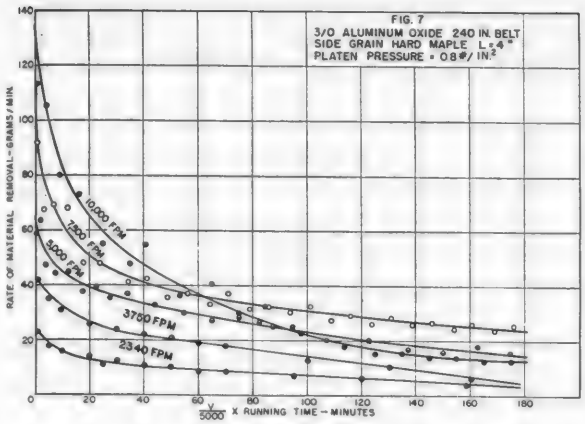
Of particular interest is the observation that aluminum oxide and garnet have approximately the same initial



rate of material removal, but that the rate drops more rapidly in the case of garnet and the comparable aluminum oxide belt is soon cutting roughly twice as fast. This appears to contradict the popular belief that garnet is the better material at low speeds. The basis for the current practice of using garnet where belt velocities are below 5,000 surface feet per minute and aluminum oxide above that speed seems to be the assumption that there is a substantial amount of fracturing of abrasive particles during machining. It is reasoned







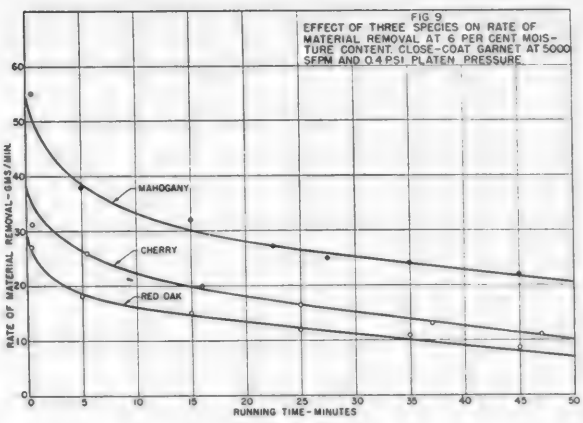
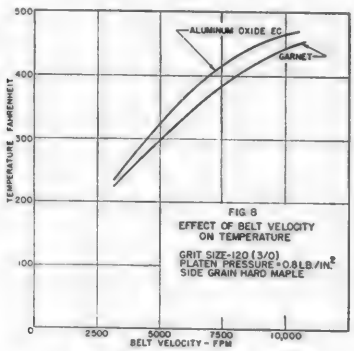


FIG 9
EFFECT OF THREE SPECIES ON RATE OF MATERIAL REMOVAL AT 6 PER CENT MOISTURE CONTENT. CLOSE-COAT GARNET AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE.
RATE OF MATERIAL REMOVAL - GMS/MIN.
MAHOGANY
CHERRY
RED OAK
RUNNING TIME - MINUTES



that at low speeds garnet fractures at such a rate that new, sharp cutting points are constantly produced, while tougher aluminum oxide grits do not fracture easily enough to give this effect. Similarly, it is reasoned that at high velocities the garnet grits will fracture too easily under the increased load and cause too rapid breakdown, thus aluminum oxide is preferred. While the above is based on years of practical experience and cannot be entirely disregarded, it is notable that in the course of many carefully controlled laboratory studies no evidence has been found to indicate there is any appreciable fracturing of garnet or aluminum oxide abrasive particles. In all cases throughout the wide range of machining conditions studied, the grit particles were found to deteriorate by abrasion.

Effect of Dressing

A brief investigation of the potentialities of dressing abrasive belts in a manner similar to that commonly used for grinding wheels was prompted by the observation that the grit particles become dull from abrasion rather than fracturing as is commonly supposed. It was thought that by using a silicon carbide stick for dressing the worn abrasive surface, the dull grits might be fractured or knocked free from the belt. Several belts of aluminum oxide and garnet were used until their cutting rates were reduced to a point where ordinarily they would be discarded. Then the surfaces were lightly dressed and the cutting rates again checked and the difference noted. It was found that after dressing, the cutting rates in terms of the grams of material removed per minute, had increased very markedly. The improvement of the belts was such that a rate of removal approaching that of the new belt was obtained. With use, however, the rate decreased rapidly to the value before dressing. Subsequent dressings had a similar but lessened effect. While the benefits of lightly dressing abrasive belts are at best temporary, it appears that in many cases the useful life of a belt can be extended by 10 to 20 percent. It must be cautioned that excessive dressing is very detrimental to the cutting life of coated abrasives.

Effect of Length of Contact Area

A limited study of the effect of contact area length has been carried out. As used here, the length of the contact area is analogous to platen length.

The clearance for chips during the interval when a portion of an abrasive belt is under platen pressure is of necessity relatively small. It is quite conceivable that when the platen is long the abrasive surface, under pressure, may become choked with wood particles. If this is the case, then the wood waste may support much of the platen pressure that is intended to be applied to the grits. This could reduce the cutting efficiency of the belt and perhaps encourage loading of the abrasive surface. To determine the effect of contact area length, garnet abrasive belts grit size 120 (3/0), were used at constant platen pressure of 0.6 psi. and velocity of 5,000 fpm. The length of the contact area varied from 4 to 10 inches. In determining the rate of material removal from this study, it was necessary to adjust data to compensate for variations in the length of time a given portion of the belt was in contact with the work piece. The corrected data could then be plotted to provide direct comparison of the results obtained. It was found that for lengths 6 inches and over, the rates of material removal were essentially identical when plotted against time. When the length of the contact area was reduced to 4 inches, however, the rate of material removal was substantially increased. This effect became more pronounced as belt wear progressed.

Surface temperatures during machining were found to vary with contact length. The values observed were 225, 250, 275, and 275 degrees F. for lengths of 4, 6, 8, and 10 inches, respectively. Loading of the abrasive belt appeared to decrease as contact length was shortened, and glazing of the wood surface was less severe. From this it would seem that minimum surface heat would be developed by a very short contact length, such as is obtained with a drum or contact wheel, assuming other conditions remain constant.

Species and Moisture Content

It is generally recognized among users of coated abrasives that different species will affect the performance and cutting life of an abrasive belt. Each species varies in its properties and offers different resistances to the forces tending to abrade them. In addition, the moisture content of the wood is of considerable importance in the performance of an abrasive belt.

Figure 9 is a plot of rate of material removal over running time for three species: Honduras mahogany, black cherry and northern red oak, at 6 percent moisture content. Close-coated animal glue-bonded garnet belts were used at a velocity of 5,000 SFPM and 0.4 psi. platen pressure.

The relationship of these curves appears to be associated to a large extent with the density of the species involved, as resistance to indentation is dependent primarily on this factor. That the less dense species, mahogany, is abraded at a higher level is indicative of the increased chip load per grit due to the greater depth of penetration of the grit particles.

Of significant interest is the slope of these curves. After approximately 15 minutes running time the curves are very

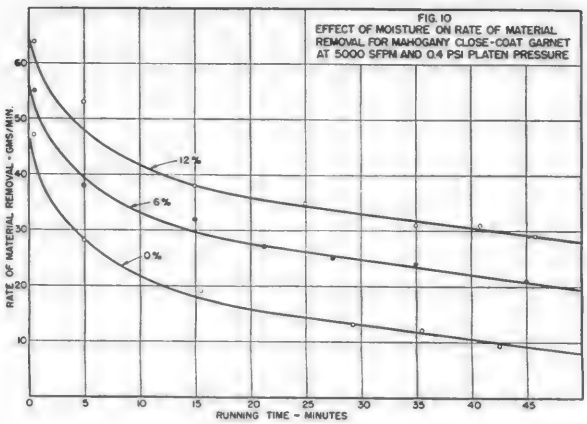


FIG. 10
EFFECT OF MOISTURE ON RATE OF MATERIAL REMOVAL FOR MAHOGANY CLOSE-COAT GARNET AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE
RATE OF MATERIAL REMOVAL - GMS/MIN.
RUNNING TIME - MINUTES
12%
6%
0%

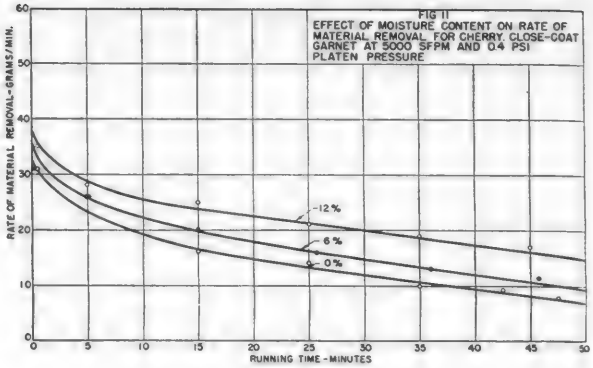


FIG 11
EFFECT OF MOISTURE CONTENT ON RATE OF MATERIAL REMOVAL FOR CHERRY, CLOSE-COAT GARNET AT 5000 SFPM AND 0.4 PSI PLATEN PRESSURE
RATE OF MATERIAL REMOVAL - GRAMS/MIN.
RUNNING TIME - MINUTES
12%
6%
0%

nearly identical in slope, indicating the cutting capacity of the belt in decreasing at approximately the same rate for the three species shown. Where loading is not a factor a loss in cutting capacity primarily can be attributed to grit wear. It is evident from these curves that grit wear is proceeding at approximately the same rate regardless of species or relative density. This can be explained when it is considered that the density of wood substance, that is, the material which makes up the walls of the wood constituents is practically the same for all species. Disregarding organic or inorganic infiltration products, one wood will weigh more or less than another at a given moisture content depending on the relative volume of wood substance and voids. Hence, in abrading wood, the actual wear of the abrasive is the result of the abrasion of the grits by the wood substance comprising the cell walls and cannot be correlated with relative density as one might imagine. However, as explained previously, relative density controls to the greatest extent the penetration of the grit particles. Thus for any given set of conditions, a larger chip will be formed with the less dense species, giving a higher rate of material removal. It is recognized that other wood factors, e.g., mineral deposits and resin accumulations, will influence the relative cutting life of an abrasive. These factors must be taken into consideration when appraising the cutting efficiency of a coated abrasive.

Sanding temperatures were somewhat lower for the less dense species than for the denser species shown. However, for the range investigated the slight difference was not considered to be significant.

Figures 10 and 11 are a plot of the effect of moisture content on the rate of material removal for two species, Honduras mahogany and black cherry, sanded at 0, 6 and 12 percent moisture content with a close-coated animal glue-bonded garnet abrasive at 5,000 SFPM and 0.4 psi. platen pressure.

The levels of these curves are undoubtedly controlled by the moisture content of the stock, being the greatest for the higher moisture content. This is indicative of the reduction in density and strength properties which accompanies an increase in moisture content. The slopes of the curves for the two species shown at the various moisture contents are again very nearly identical. From this it may be assumed that moisture content does not influence rate of grit wear appreciably.

Sanding temperatures were slightly lower for the higher moisture contents, but as before, the temperatures developed between the various moisture content levels were not considered to be significantly different.

Cupping of the abrasive belts showed a pronounced increase as the moisture content of the stock being sanded was increased. This is apparently due to the absorption of moisture by the adhesive causing an expansion of this film. As the swelling stresses imposed upon the adhesive are greater than those caused by the paper the belt will tend to cup toward the backing. The greater the degree of moisture absorption by the adhesive, the greater is the resulting belt cup. Aiding this is the shrinkage of the backing that may occur due to moisture being driven from the paper as a result of the frictional heat generated through contact with the platen. Reverse cupping or cupping towards the adhesive will take place if the magnitudes of these stresses are for some reason reversed.

Conclusions

It would appear from the results of this investigation that the life of an abrasive belt is governed by two principal factors; the abrasion resistance of the grit particles, and the loading of the belt. The former is a characteristic of the abrasive material alone, while the latter is dependent on the structure of the abrasive belt, the conditions of machining, and the wood being machined.

Loading of abrasive belts seems to be primarily dependent on the surface temperature developed on the work piece. As working temperatures reach the range where wood plasticizes and begins to scorch, loading takes place rapidly. Pressure, belt velocity, length of contact area, grit size, and belt structure are among the factors that govern the amount of heat generated. Loading is also influenced by certain species characteristics such as the resin contained in some woods.

The use of contact wheels rather than long platen surfaces or drums is suggested where practical. Short contact areas appear to reduce machining temperatures and permit higher rates of material removal. Glazing of the work surface seems to be less severe when short contact areas are employed. In contact sanding where belt wear is distributed over a greater area than is the case with drum sanding due to increased belt length the ratio of operating time to down time would be considerably improved.

Dressing abrasive belts in much the same manner as grinding wheels deserves consideration. Limited investigation showed that greatly increased rates of material removal followed dressing of worn belts with a silicon-carbide stick. Reduction of wood surface glaze accompanied dressing.

High surface temperatures, resulting from excessive pressure or extreme velocities, can accelerate the deterioration of a belt. It is possible to load a belt and destroy its efficiency in a matter of seconds through improper control of conditions.

The effect of species on belt wear seems to be controlled by the actual wood substance and not by relative density, although the latter determines depth of cut for a given pressure, thereby limiting the rate of material removal.

The rate of material removal increases as moisture content increases at a given pressure by reason of the reduction in resistance to penetration of the grit particles.

TECHNICAL SESSION IV—Thurs., May 6, 1954, 1:30 P.M.

Subject: Wood Drying

Chairman: Raymond C. Rietz

Recorder: Howard Rosenberry

Improving the Thermal Efficiency of Dry Kilns

ROBERT J. HOYLE, Jr.

Research Assistant, College of Forestry, State University of New York, Syracuse, New York[1]

The importance of good vent control and the feasibility of recovering heat from the vented air of dry kilns are discussed. The heat consumption of compartment-type kilns with poor vent control was found to exceed twice that of kilns with well designed automatic vent controls. Heat recovery systems may effect savings of 4½ to 9 percent of the heat consumed.

SCRAP WOOD, in an increasing number of woodworking plants no longer finds its most profitable use as fuel. The result is an increasing use of coal, oil, or natural gas in the plant boilers—either full or part-time—and an increasing need to scrutinize the cost of fuels and the possibilities of conserving heat.

Why Reduce Heating Costs?

Many of the older dry kilns in use today waste much heat. The purpose of this paper is to show how wasteful of heat such dry kilns can be, and to suggest ways of improving their efficiency. Modern dry kilns, which employ forced air circulation and automatic temperature and humidity control systems, are, of course, highly efficient when compared to the older kilns.

Investigations have shown that fuel costs associated with drying can be reduced by as much as $3.66 per M b.m. depending on species, moisture content reduction and type of dry kiln, by the use of a good system of humidity control. Heat recovery methods may further reduce heating costs as much as 25 cents per M b.m. Labor and equipment investment costs to generate steam have not been considered, but in plants of considerable size these costs may equal the cost of fuel.

Heat Consumed in Kiln Drying Lumber

The heat consumed by the drying process in a ventilated kiln may be said to serve six distinguishable purposes: (1) Heating and evaporating the water removed from the wood; (2) Heating the water which remains in the wood when the final moisture content has been reached; (3) Heating the wood substance; (4) Overcoming hygroscopic force. Below the fiber saturation point the moisture is held in the cell walls by molecular forces. Heat, over and above that required to evaporate free water, is needed to break these bonds; (5) Supplying the transmission and leakage losses and warming the kiln structure to operating temperature; (6) Warming and humidifying the fresh intake air. Ventilated kilns rid themselves of the moisture issuing from the lumber by venting moisture laden air and taking in cool dry air. The intake air must be heated to kiln temperature before it is passed over the lumber. The balance between rate of venting and rate of evaporation is very delicate and can seldom be exactly maintained. When the rate of venting exceeds that required to relieve the kiln of evaporated water an excess of cool dry air enters the kiln. This excess air must be humidified by spraying steam or finely atomized water into the drying chamber.

The relationship between these elements is shown in Fig. 1. The ideal kiln would vent exactly enough air to carry off the exaporated water. Usually, however, even the best of kilns will release a small amount of excess air, somewhere between 5 and 25 percent; poorly controlled kilns may release 200 percent, or more.

The first four elements of heat consumption are essential to the drying process and little, if anything, can be done to reduce them. The two remaining elements can be controlled by insulation and maintenance of the kiln structure, by reducing drying time to a minimum (heat losses, element No. 5, are almost directly proportional to drying time), by accurate control of venting, and by recovering heat from the vent air to warm the cold intake air. If the value of heat and the cost of insulation and labor to install it are known, it is not a difficult matter to establish the proper amount and kind of insulation to apply to the kiln structure to reduce the transmission losses. As shown in Figure 1 the heat used to replace losses and to heat and humidify intake air represent a large portion of the total heat consumed in drying lumber, consequently reductions in these elements will be most effective in increasing thermal efficiency. This paper concerns itself primarily with element No. 6—the heat required to warm and humidify the vented air.

Uncontrolled Venting Wastes Heat

Kiln drying specialists have recognized the importance of keeping vented air to a minimum, and have emphasized this fact for many years. However, the actual amount of heat which is wasted by poor vent operation is not mentioned in literature on the subject. In recent tests the flow of vent air was measured for several dry kilns

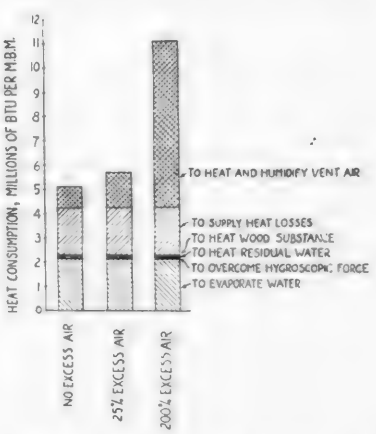


Figure 1.—Distribution of elements of heat consumption for a 20 M b.m. compartment type dry kiln, drying 4/4-in. sugar maple from 72 to 6 percent moisture content in 14 days.

[1] The author wishes to acknowledge with appreciation the aid of Professor Alfred H. Bishop, Department of Forest Utilization College of Forestry, State University of New York, in planning and carrying out the research.

ABOUT THE AUTHOR: HOYLE, ROBERT J. JR., Sessions III and IV, Wood Machining and Wood Drying, "Wood Machining Research with High Speed Motion Pictures" and "Improving the Thermal Efficiency of Dry Kilns" . . . In charge of wood machining research at the College of Forestry, State University of New York, Syracuse, New York . . . attended Cornell University and the College of Forestry, State University of New York . . . degree of B. of ME in 1941 and MS degree in Forestry in 1952 . . . formerly associated with Taylor Instrument Companies, Eastman Kodak Company and the Timber Engineering Company . . . Member of FPRS, A.S.M.E. and Sigma Xi.

Table 1.—RESULTS OF VENTING STUDY FOR THREE DIFFERENT DRY KILNS (MB.M. BASIS)

	Natural-circulation kiln. No vent damper control	Forced-circulation kiln	
		Manual vent dampers	Automatic vent dampers
Material	6/4-in. sugar maple	4/4-in. black willow	4/4-in. sugar maple, 4/4-in. black cherry
Water evaporated, lbs.	277	169	255
Vent air required, lbs.	4,770	1,300	4,240
Actual amount of vent air, lbs.	21,860	8,110	5,275
Excess vent air, percent[1]	360	527	25
Heat consumed by excess vent air, thousands of Btu.	2,370	1,175	102
Cost of excess vent air[2]			
dollars per Mb.m.	1.17	0.58	0.05
dollars per lb. of water evaporated	0.0042	0.0034	0.0002

[1]In percent of the amount of vent air required to rid the kiln of evaporated water.
[2]Based on heat valued at 0.000495 dollars per thousand Btu.

in commercial operation and the results showed that accurate vent control can reduce heat consumption to half of that used by kilns with poor vent control. The types of kilns studied included: (1) Natural-circulation, ventilated, end-piled dry kiln with automatic control of steam supply to the heating coils and spray lines, but without vent damper control. (2) Forced-circulation, ventilated, cross-piled dry kiln with automatic control of steam supply to the heating coils and spray lines and manual vent damper control. (3) Forced-circulation, ventilated, cross-piled dry kiln with automatic control of steam supply to heating coils and spray lines and automatic vent damper control.

The drying schedules and initial moisture content, size, and species of wood in these kilns were not indentical. Exact duplication of these conditions would have been desirable; nevertheless the results are significant. The initial moisture contents of the lumber dried in these three kilns were 72, 19, and 16 percent, respectively; the final moisture contents were 6.5, 4.1, and 6.4 percent. For the purpose of comparing venting rates those parts of the drying processes between 16 and 6.5 percent are presented in Table 1. The vastly superior performance of the forced-circulation kiln with automatic vent damper control is evident. The air vented from this kiln was only 25 percent above the ideal minimum. For the forced-circulation kiln with manual vent damper operation the vent air was over five times the ideal minimum (measured on the basis of pounds of dry air) and for the natural-circulation kiln with no vent dampers it was three and one-half times the ideal minimum. One may question the results for black willow, which was used in one of the test cases, because its drying characteristics are different from those of sugar maple, and black cherry. By making proper corrections for the influence of this lower density, faster drying species (black willow) it was found that if sugar maple had been used for that charge the percent and cost of excess vented air, both per Mb.m. and per pound of water evaporated, would have been about the same as the results shown in the first column of Table 1. These results show that manual vent dampers offered little improvement in vent control. The driving pressure causing ventilation in a forced-circulation kiln is much greater than in a natural circulation kiln without any vent damper control, but increased attention to the manual venting operation on the part of the kiln operator could have reduced the excess air measurably.

Results for a charge of 6/4 sugar maple, dried in the natural-circulation kiln, are presented in Table 2. The cost associated with the excess vented air in drying from the green condition was about three times that required in drying from an air-dried condition of 16 percent moisture content.

Cost of Excess Venting

The cost figures are based on the use of coal as fuel. If a typical bituminous coal with a heating value of 13,000 Btu. per pound and valued at nine dollars per ton is burned in a boiler at 70 percent efficiency, the cost of fuel will be 0.000495 dollars per thousand Btu. The cost of the excess vent air are presented in Tables 1 and 2. In the case of the natural-circulation dry kiln (capacity 20 Mb.m.) without vent control the annual cost of excess vented air will approach 400 dollars. For the forced-circulation kiln (capacity 12 Mb.m) with manual vent controls the annual cost would be about 250 dollars. In these cases fuel savings of 250 to 400 dollars per year would result from better vent control and the investment in vent dampers, diaphragm motors, and labor to install them would be readily justified.

In this report fuel is the only cost considered. If the labor and the equipment investment in the boiler room are considered, the cost of excess vent air is estimated to be approximately double the figures given here.

Table 2.—EXCESS VENTED AIR RESULTS IN DRYING 19,280 BD. FT. of 6/4-IN. SUGAR MAPLE FROM 72 TO 6.5 PERCENT MOISTURE CONTENT IN A NATURAL CIRCULATION KILN WITH NO VENT DAMPER CONTROL[1]

Moisture content, percent	72 to 30	30 to 6.5	72 to 6.5
Drying time, days	12	9	21
Water evaporated, lbs.	23,500	13,200	36,700
Vent air required, lbs.	384,800	219,190	603,990
Actual amount of vent air, lbs.	1,246,250	814,740	2,060,990
Excess vent air percent[2]	224	270	240
Heat consumed by excess vent air, thousands of Btu.	72,050	71,025	143,075
Cost of excess vent air[3]			
dollars per Mb.m.	1.84	1.82	3.66
dollars per lb. of water evaporated	0.00151	0.00265	0.00192

[1]The drying process is divided into two parts to permit comparing cost of venting both above and below 30 percent moisture content.
[2]In percent of the amount of vent air required to rid the kiln of evaporated water.
[3]Based on heat valued at 0.000495 dollars per thousand Btu.

Heat Recovery from the Vented Air

In steam heated kilns cold intake air is usually mixed with recirculated kiln air prior to heating. In some kilns a pre-heater in an intake air duct warms this air to kiln temperature before it mixes with the kiln air. In either case the heat absorbed by the intake air is 15 to 25 percent (basis of modern kiln with automatic vent damper operation) of the total kiln heat requirements, varying somewhat with species and lumber thickness. Concurrently the kiln is exhausting hot vent air which could be used for warming the intake air by use of an air-to-air heat exchanger.

The principle of heat recovery has received some attention in the United States but has not been widely adopted, probably for economic reasons. Its application to electrically heated kilns was described in recent literature.[1] In Sweden and other northern European countries heat recovery is in accepted use on progressive type dry kilns.

A small heat exchanger was constructed in the laboratories of the College of Forestry, State University of New York in 1951. Tests showed that cold intake air at approximately 75 deg. F. could be heated to within 15 to 30 deg. F. of the kiln temperature,

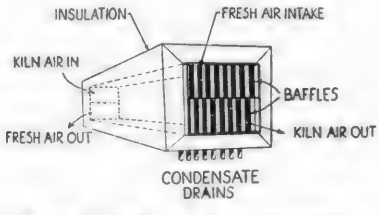


Figure 2.—End view of heat exchanger.

[1] *The Lumberman*, Nov. 1953. "New All Electric Dry Kilns Announced." Vol. 80, No. 12, p. 136.

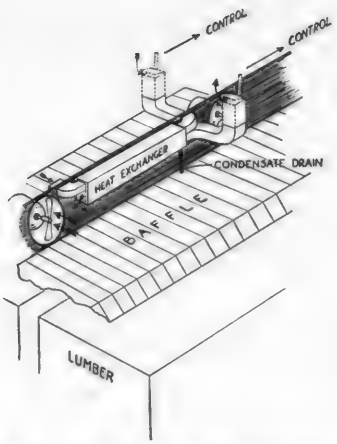


Figure 3.—Heat exchanger installed in a compartment-type dry kiln.

depending on the relative humidity of e vented air.

The Experimental Heat Exchanger

The heat exchanger consisted of 15 parallel copper plates, 0.0179 in. thick, 6 by 78 in. overall size, spaced 0.375 in. from one another. This provided a total surface area of 49 sq. ft. Hot vented air and cold intake air flowed counter-currently in alternate passages between plates. This heat exchanger is illustrated in Fig. 2. The tubular outlets on the bottom are to drain condensate from the cooling vented air.

This unit was designed to preheat air for a small dry kiln of five M b.m. size when drying northern white pine. If used for hardwoods, e.g. sugar maple, it would have capacity to preheat aid for about ten M b.m. kiln capacity. The unit was intended for use on a compartment type kiln and might be installed as shown in Fig. 3. Air flow would be caused by the pressure drop across the circulating fans. Reversing the circulation would not alter the effectiveness of the heat exchanger. One large heat exchanger or several small ones could be used on commercial size dry kilns.

Results of Heat Exchanger Tests

Temperatures and humidities at the inlets and outlets to the heat exchanger were obtained with thermocouples and a potentiometer. Wicks were used to cover the wet bulb thermocouples. A vane type anemometer was used to determine the air flow. The test results are presented in Fig. 4. Cool dry air entered the heat exchanger at about 75 deg. F. The effect of humidity on heat transfer rate is clearly evident, and is due to the differences in amount of heat transfer surface wetted by the condensate from the cooling kiln air.

Separate curves are presented for four humidity conditions. Kiln air at 20 percent relative humidity was cooled without condensation of water vapor. At the other humidities some condensation took place. As anticipated, the heat transfer capacity increased when condensed water vapor wet the plates. The heat transfer coefficient was about 2.73 Btu. per hr., sq. ft., deg. F. for dry plates and 5.25 Btu. per hr., sq. ft., deg. F. when the plates were almost completely wet. The air velocity was 10 to 15 ft. per sec., varying somewhat with temperature.

The pressure loss between the kiln air inlet and the intake air outlet of the heat exchanger was 0.18 in. of water. In a well designed dry kiln with proper baffling and adequate circulation the pressure loss through the lumber would be about 0.25 in. of water. This pressure, created by the fans, is more than sufficient to cause air flow in the heat exchanger.

Significance of Heat Recovery

The tests established basic heat transfer coefficients, air friction losses in the heat exchanger and the practicability of certain design details. These data made it possible to determine heat recovery possibilities by calculation. Such information was developed for 4/4 eastern white pine and 6/4 sugar maple dried from 80 to 6 percent and 72 to 6 percent, respectively.

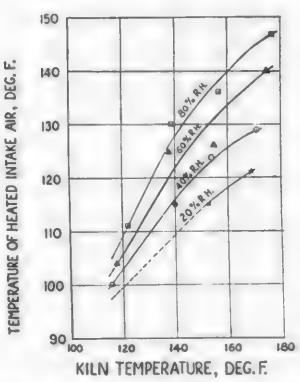


Figure 4.—Heat exchanger test results for a cold intake air temperature of 75 deg. F.

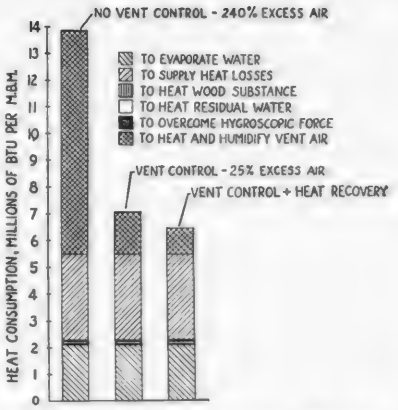

NO VENT CONTROL - 240% EXCESS AIR
TO EVAPORATE WATER
TO SUPPLY HEAT LOSSES
TO HEAT WOOD SUBSTANCE
TO HEAT RESIDUAL WATER
TO OVERCOME HYGROSCOPIC FORCE
TO HEAT AND HUMIDIFY VENT AIR
VENT CONTROL - 25% EXCESS AIR
VENT CONTROL + HEAT RECOVERY
HEAT CONSUMPTION, MILLIONS OF BTU PER M.B.M.

Figure 5.—Heat consumption graph for a 20 M b.m. dry kiln, drying 6/4-in. sugar maple from 72 to 6 percent moisture content in 21 days.

The results, for both summer and winter conditions in Central New York State are presented in Table 3. Drying schedules were selected from U. S. Forest Products Laboratory Report D 1791.

Annual fuel savings for a compartment type dry kiln with 50,000 bd. ft. capacity per charge are estimated to be $190 for eastern white pine and $390 for sugar maple. These figures are based on fuel costs mentioned earlier.

The cost for manufacture and installation of a heat exchanger is not known. Costs for the laboratory model would not be a sound basis for an economic analysis and cost information on suitable equipment has not been available. A Swedish manufacturer of dry kilns and heat transfer equipment, A. B. Svenska Fläktfabriken, Stockholm, Sweden, has provided cost information on heat exchangers suitable for large capacity progressive type dry kilns using forced draft fans to insure air movement in the heat exchanger. The costs indicate that application of the heat recovery method to progressive type dry kilns would be economically feasible.

The case for application of the heat recovery principle to compartment type kilns is not quite so strong as for progressive types. Heat exchangers on progressive type kilns are more efficient because the vent air is always being drawn off the entrance end of the kiln where the relative humidity is high. It follows that the heat transfer plates will be wet and that the higher heat transfer coefficients will apply. The heat transfer coefficients can be raised by increasing the air velocity through the heat exchanger, thus reducing the surface area required. The heat recovery equipment manufactured in Sweden employs higher air velocities than those used with our laboratory model.

Table 3.—ESTIMATED HEAT RECOVERY FROM THE VENTED AIR OF DRY KILNS (MB.M. BASIS)

Species	Moisture content range, percent	Intake air temperature, deg. F.	Intake air relative humidity, percent	Heat recovered, thousands of Btu.	Value of heat recovered dollars
N. white pine (4/4-in.)	80–6	35	80	258.5	0.130
N. white pine (4/4-in.)	80–6	80	50	152.3	0.070
Sugar maple (6/4-in.)	72–6	35	80	504.8	0.251
Sugar maple (6/4-in.)	72–6	80	50	302.2	0.143

Heat recovery, according to the test results, would be 4.5 to 9 percent of the total heat consumption for a compartment type kiln. With the Swedish made equipment reductions of 7 to 20 percent in heating requirements are reported for progressive type dry kilns.

Conclusions

The vent air measurements show that compartment type kilns without vent air controls may consume twice as much steam as well maintained kilns with automatic vent dampers. The individual kiln operator must determine the feasibility of installing automatic vent dampers. Some kilns are not well suited to vent damper controls because of design features. The kiln manufacturer or a qualified kiln engineer should be consulted before such an installation is made. If the cost of heat is 0.0005 dollars per thousand Btu. the installation of vent damper controls would bear investigation.

The amount of heat recoverable from the vented air of well-designed kilns with accurate vent damper controls is small compared to the effective savings obtainable by use of a good system of vent air control, as can be seen in Fig. 5. In improving the thermal efficiency of kilns attention should first be given to providing good vent control. Secondly, attention to reducing heat losses by insulation of the kiln structure would yield sizable heat savings. And thirdly, attention to heat recovery methods could yield savings although they probably would be smaller than those obtainable by vent control and insulation.

Discussion

John Welch (Standard Dry Kiln): Automatic controls have been great improvement over old methods of damper control.

John Devine (Moore Dry Kiln): What kind of hardwoods?

Mr. Hoyle: The species of maple used was hard or sugar maple (Acer saccharum). Other species dried in these tests were black cherry (Prunus seratina) and black willow (Salix nigra).

Steam Consumption in the Kiln Drying of Western Softwoods

VIRGIL C. DAVIS

Assistant Superintendent, The Booth–Kelly Lumber Company, Springfield, Oregon

This is a study of steam consumption data collected from the kiln drying records of The Booth Kelly Lumber Company in Springfield, Oregon.

The study includes the total footage dried in a consecutive number of months of production, total pounds of steam consumed, total pounds of moisture evaporated and pertinent related facts.

The western softwoods that are involved are Douglas fir *(Pseudotsuga taxifolia)* and western hemlock *(Tsuga heterophylla).*

Introduction

CONSERVATION OF STEAM in the seasoning of lumber is a matter of real importance to the lumber industry today. One reason for this is the trend toward complete use of wood formerly wasted.

In the past it was often a problem for a mill to dispose of it's waste. Huge refuse burners burned twenty-four hours a day, seven days a week. The fuel supply to generate steam for the dry kilns was almost unlimited. Now with better use of residues, these burners are falling into disuse and often disappearing completely.

With the perfection of the hard board materials, the installation of barkers, and the production of bark-free chips, residues no longer can be economically used as fuel.

It is therefore imperative to be on the alert for ways and means to reduce steam consumption in the seasoning of lumber, and to gage steam requirements carefully.

Variables Affecting Steam Consumption

In considering the consumption of steam in drying western soft woods in kiln batteries it is desirable to recognize all of the variables.

Insulation is a big factor in steam conservation in dry kilns. A large steam saving is realized with insulation on the roofs and on the steam supply lines. The inside of the kilns should be covered with a heavy coat of vapor seal. The kilns in this study have insulated roofs, insulated steam supply lines and vapor seal on the inside of the kilns. Meter readings revealed that consumption was cut one third with an adequate roof insulation.

Doors should be tight to avoid the loss of heat and humidity and the need for more steam to replace the loss.

Equipment maintenance is important. Any equipment that is not in proper condition will cause a waste of steam. Leaking steam traps and valves run kiln steam costs unnecessarily high, yet this condition is common in some operations.

Quick reloading of kilns will reduce heat loss from kiln buildings. This is one variable that can be controlled providing there is enough green lumber available to reload the kiln as soon as it is discharged. It takes one to two hours to reload a kiln charge at the Booth–Kelley Springfield plant.

Steam can be saved by using a split schedule. This method consists of lowering the wet bulb to increase the depression instead of raising the dry bulb temperature. By doing this, the same drying results can be obtained without increasing the heat of the lumber or the kiln building. It has been observed that it takes less steam to reheat the air that is replaced by venting, than to increase the temperature of the lumber and building. This fact can be used to an advantage at certain times in schedule changes. Steam for other than the evaporation

ABOUT THE AUTHOR: DAVIS, VIRGIL C. Speaker, Session IV, Wood Drying, "Steam Consumption in the Kiln Drying of Western Softwoods" . . . Assistant Superintendent of the Booth–Kelly Lumber Company, Springfield, Oregon . . . Twenty-five years experience in the seasoning of lumber . . . formerly connected with Multnomah Lumber and Box Company . . . present president of the West Coast Dry Kiln Club.

of the moisture from the lumber may run as high as three-fourths or more of the total steam used. The heat loss through buildings and supply lines is very great, so prolonged schedules would run the steam consumption up unnecessarily high. All schedules used during the study reported in this paper were based on minimum time for maximum quality.

Steam consumption is of course, much higher in the winter than in the summer. The lower the temperature of the outside air, the more steam needed to heat it as it comes into the kilns. Ice and frost on lumber would use extra steam to bring it up to the desired temperature, and there is more heat loss through the building in freezing, weather.

Weather conditions during the time of this study were comparatively mild. Average temperature during the study was 52.8 degrees.

Since it takes more steam to dry lumber as lower moisture contents are reached, it increases steam consumption to dry lumber to a moisture content lower than is required. Kiln samples were used at the Booth–Kelly operation to determine the moisture content and time to end drying.

Reconditioning lumber is another factor in steam consumption, for some operations do not spray with steam to raise humidity; still others recondition every charge dried.

All charges are reconditioned at Booth–Kelly. This should be kept in mind when reading the average figures on steam consumption to fellow. This is one place in the operation that steam is not spared.

Quite often kilns will have to spray to restore the proper humidity immediately after venting. A kiln that has a tendency to over vent will waste steam. It is readily observed that a kiln building that is tight in construction and has automatic venting will use the moisture evaporated from the lumber to maintain the humidity, thus using less spray and less steam. In the kilns studied, no spraying was needed from over-venting.

Other variables could be listed, but these are the important ones.

Method of Measuring Steam

At the Booth–Kelly Lumber Company the steam is measured by a Bristol mechanical flow meter of the restricted orifice type installed on the main supply line to the dry kilns. This measures all the steam going to the kilns, including loss in the supply line, spray used in kilns and steam used by heating coils. It is necessary to measure the steam since it is purchased from an adjacent steam plant.

Kiln Description

The Booth–Kelly Lumber Company has a battery of 10 R. A. Simmons internal-fan, cross-circulation dry kilns 103 feet long, constructed of reinforced concrete. Each kiln has four propeller-type fans, one at each corner of each kiln in an overhead duct system. The fans at each end work in tandem. All fans are reversible.

The kilns are all single track with doors on one end, and equipped with the latest type Foxboro instruments. There are twelve 1-inch fin pipes straight through the kiln with the header at the door end. Most of the drying requires only half of the coils.

The lumber is piled flat and loaded by an overhead crane. It is the practice to leave a vertical space of 6 inches between units and a horizontal space 5½ inches between bottom and top units.

Results and Computations

The average green moisture content assumed for fir was 40 per cent, hemlock common 100 per cent, and hemlock clear 110 per cent. This was determined by taking a series of green moisture content samples.

The rough green weight per thousand board feet was taken from West Coast Lumberman's Association shipping weights.

The following shows how pounds of moisture evaporated per thousand board feet was calculated:

$$\frac{\text{Original green weight}}{1 \text{ plus } \frac{\text{Moisture content in percent}}{100}} = \text{oven dry weight per thousand.}$$

Oven dry weight × (100 plus current moisture content) = weight per thousand at current moisture content.

Original weight — current weight = pounds of moisture evaporated per M board feet.

The fir clear is dried to 8 percent moisture content; common fir to 19.4 percent, clear hemlock to 8 percent, and the common hemlock to 10 percent.

The following shows the species and grade, original green weight per thousand, original moisture content, pounds of moisture evaporated per thousand board feet, and current moisture content:

Species	Original green weight per M	Original moisture content percent		Lbs. of moisture evaporated per M	Current moisture content percent
Clear fir	3,500	40	—	800	8.0
Common fir	3,500	40	—	486	19.4
Common hemlock	3,800	100	—	1,710	10.0
Clear hemlock	4,000	110	—	1,948	8.0

The following table of moisture loss is for a consecutive number of weeks of operation:

Species	Footage	Lbs. of moisture evaporated per M	Total moisture evaporated
Clear fir	16,481,203	800	13,184,962
Common fir	4,255,418	486	2,068,133
Common hemlock	4,442,257	1,710	7,496,259
Clear hemlock	295,268	1,948	575,183
Total	25,474,146		23,324,537

The total amount of steam consumed to kiln-dry this total amount of footage and evaporate the pounds of moisture indicated above was 60,171,200 pounds.

Averages:

2,358 pounds of steam consumed per thousand board feet.

2.57 pounds of steam consumed per pound of moisture evaporated.

2.35 pounds of steam consumed per board foot.

It is generally agreed that it takes one pound of steam to evaporate one pound of water, conditions being perfect. Therefore, using the figure of 2.57 pounds of steam to evaporate a pound of moisture in the Booth–Kelly battery of kilns, it could be assumed that 1.57 pounds of steam was the average amount of steam loss per pound of moisture evaporated.

The following is a table showing the relation in percentage of each item to the total amount of footage and to the total amount of moisture evaporated:

Species	Percent of total footage	Percent of total moisture evaporated
Clear fir	64.700	56.528
Common fir	16.704	8.867
Common hemlock	17.438	32.139
Clear hemlock	1.158	2.466

Assuming that the same percentage of steam is consumed to evaporate the same percentage of moisture, 56.528 percent of the total moisture evaporated from clear fir would require 56.528 per cent of the total steam consumed, therefore:

Species	Lbs. of steam consumed	Lbs. of steam per M bd. ft.
Clear fir	34,013,576	2,064
Common fir	5,335,380	1,254
Common hemlock	19,338,422	4,353
Clear hemlock	1,483,822	5,025

It should be noted that the item of clear fir with the figure of 2,064 lbs. of steam consumed per thousand board feet included 14 percent 2-inch lumber. Therefore 1-inch clear fir dried with a 72 hour schedule would take less steam than 2,064 lbs. per thousand, and the 2-inch fir clear dried with a 156-hour schedule would require more.

This would also be true with the common hemlock for there was also a percentage of 2-inch common Hemlock dried.

Seasonal variations were as follows:

Summer: At an average temperature of 58.9 degrees 12,545,957 bd. ft. consumed 26,360,000 lbs. of steam or 2,101 lbs. per thousand bd. ft.

Winter: At an average temperature of 46.7 degrees. 12,928,189 bd. ft. consumed 33,811,200 lbs. of steam or 2,615 lbs. per thousand bd. ft.

Discussion

N. T. Shelton (Diamond Match Co.) What thickness of lumber are you referring to in your measure of steam consumption per 1,000 b.f.

Mr. Davis: The item of clear fir referred to in my paper consisted of all Clear Fir 2 in. and 1 in. thick with 14 percent of this item consisting of 2 in. thick Clear Fir.

W. R. Warner (Southern Lumber Company): What temperatures and schedules were used?

Mr. Davis: With fir common a relatively low temperature of 150 degrees is used to leave pitch around the knots. Common fir is dried 66 hours with final temperature at 150 degrees. The following is our schedule for 2 in. boards:

Hrs.	W.B. Temp.	D.B. Temp.
0–24	130 dg.	140 dg.
24–36	130	145
36–48	130	150
48–66	125	150
66–72	145	6 hrs. steaming—150

Final M.C.: 18 to 20 percent.

The Outlook for High-Temperature Seasoning in Canada[1]

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Fundamental considerations necessary to evaluate high-temperature seasoning from the industrial standpoint are discussed and include such factors as initial and operating costs of high temperature kilns, relative drying times and efficiencies, the possibility of adapting existing kilns and the changes in kiln organization and routine that the installation of high temperature kilns would involve.

It is tentatively suggested that such kilns would probably be most suitable for the smaller plant, where fluctuating requirements mean that small loads must be dried with as little delay as possible.

Introduction

THE KILN DRYING of lumber at high temperatures has received much attention during the past two or three years. The possibility of reducing the time and cost of lumber drying is, of course, of great interest to the wood-using industries, and the development of this process has attracted a great deal of attention. An aggressive sales campaign by manufacturers of high temperature kilns has also contributed significantly to the interest in this method of drying.

The process has been under critical examination in Europe for some time, but, until recently, little or no technical data directly applicable to Canadian conditions existed. Some two years ago, however, the Forest Products Laboratories of Canada, Department of Northern Affairs and National Resources, began a series of investigations to provide the necessary research information on high temperature drying. Considerable progress has been made but much research remains to be done. The commercial practicability for Canadian industrial conditions of seasoning or drying lumber at high temperatures is far from being proven. The laboratory investigations are barely beyond the exploratory stage. Assuming research shows high temperatures to be a practical possibility, the development of industrial techniques is, at the moment, a matter of speculation. Thus this paper is in the nature of a commentary on the past and present status of high-temperature seasoning, on the relationship of research to this field, and, in broad terms, on the problems that may have to be faced in the future, should the process prove acceptable to industry.

History of High-Temperature Seasoning

In general, the temperatures used in conventional kilns are between 100° and 200° F. The boiling point is not exceeded. The reason for this is that above 212° F. a different physical process is set up and drying occurs at a rate that has been generally considered to be too dangerous for practically every species.

However, as early as 1917, H. D. Tiemann devoted several sections of his book, "The Kiln-Drying of Lumber" to drying at temperatures above the boiling point and various experiments are described. Some nine years before this, patents were granted in the United States for kilns and drying processes involving temperatures above 212° F. By the early 1920's, commercial kilns of this nature were in operation, mainly on the West Coast. A handbook issued in 1923 by the United States Forest Products Laboratory mentions the process. A brief investigation using temperatures of around 220° F. and very high humidity was undertaken, in cooperation with an industrial firm, by the Forest Products Laboratory in Vancouver.

These high temperature kilns did not remain long in favour, principally because of prohibitively high operating costs and rapid deterioration of

[1] A contribution of the Ottawa Laboratory, Forest Products Laboratories of Canada, a Division of the Forestry Branch, Department of Northern Affairs and National Resources, Canada.

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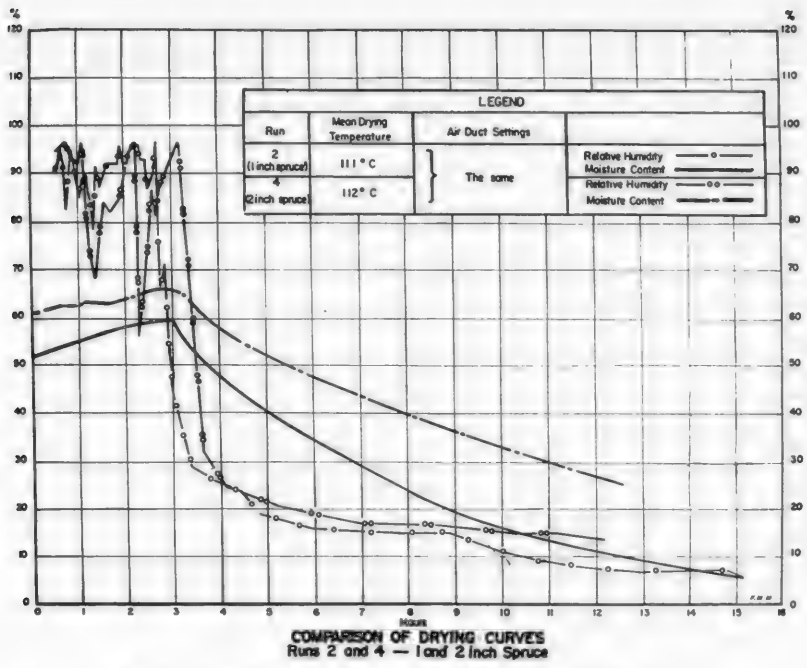

Figure 1.—Comparative drying curves for 1- and 2-inch spruce.

equipment under the severe conditions imposed upon them. Lack of knowledge regarding the basic relationships involving degree of superheat, relative humidity above the boiling point, and the moisture content of wood may have led to poor control and thus to poor quality in the end product.

In 1940, German investigators turned their attention to the problems connected with drying wood at temperatures above the boiling point of water, and also investigated the relationship of wood to the drying medium. Following experiments by a number of research workers—using pilot kilns—it became obvious that certain species responded quite favourably to high temperature drying, and it was not long before German manufacturers were designing, building and marketing kilns specifically designed to operate at high temperatures. By the use of aluminum and anti-corrosive paints, deterioration was guarded against, whilst features such as close-fitting doors and steam-tight, well-insulated walls reduced heat losses to a minimum.

Canadian Developments

As early as July 1951, the Ottawa Laboratory of the Forest Products Laboratories of Canada was receiving information regarding the European development of these kilns through representatives of the Department of Trade and Commerce in Stockholm. Several reports followed from the same source and inquiries from interested industrial groups in Canada began in December, 1951.

Meanwhile, several European-built high-temperature kilns had arrived in Canada and, by the spring of 1952, two had been inspected by members of the Ottawa Laboratory staff. After these inspections, and with interest on the part of industry mounting, it was decided to initiate an investigation into this method of drying. This decision was endorsed and strengthened by recommendations of the Technical Sub-Committee on Lumber Seasoning, of the Laboratory Research Advisory Committee.

Shortly after this the offer of a German manufacturer to loan one of his kilns was accepted, the purpose being the evaluation of the process and not determination of the efficiency of the kiln itself.

This particular kiln is of semi-commercial size and has a capacity of 500 ft. b.m. of lumber. It is heated electrically and has one steam line for humidification. The drying temperature is controlled by a thermostat, but there is no means of automatically controlling the humidity, though the rate at which the humidity falls during the drying period can be controlled to a certain extent by air intake and exhaust valves.

Preliminary tests were commenced in September, 1952. A report, "High Temperature Kiln Drying of Canadian Wood—Exploratory Investigations—Softwoods" (Mimeograph 0–170), covering the various species of softwoods dried, was published in May, 1952. Tests were continued with yellow birch and the preliminary investigation was finally concluded in August, 1953.

Results of Preliminary Investigation

The following are extracts from Mimeograph Report 0–170 which is concerned with the tests carried out with the softwood species:

"Results of the preliminary investigation have been encouraging, but a great deal of further work—including the drying of hardwoods—is necessary before the effectiveness and value of the high temperature process can be reliably determined.

"The major shortcoming of the process appears to be the great moisture content variation in the dried charge—both with individual boards and throughout the charge. However, indications are that furthur study and experimentation will show that this variation can be brought to acceptable limits.

"The amount of degrade has not been high. It was conjectured that excessive discolouration would occur, and that this would be a major objection to the process. Such discolouration has not occurred in the species dried so far.

"No recommendations regarding the application of the process on a

Figure 2.—Charge of eastern white pine dried at an average temperature of 230° F. The moisture content was reduced from 113 percent to 9 percent in 42 hours.

large scale can be made on the basis of these exploratory investigations. Assuming that the efficiency of the process can be proven, further extensive research will be necessary before drying schedules can be recommended."

The hardwoods did not respond as favorably as did the softwoods, (some collapse and honeycombing did occur) but, in essence, the conclusions reached after the softwood tests were not materially changed by the hardwood tests conducted later, and they can be considered to be applicable to the whole of the preliminary investigation.

The latter tests emphasized a fact that had become apparent during the early stages of the investigation, namely, that the particular kiln in use did not lend itself to precise experimental work, and that certain important factors could not be evaluated until suitable equipment was used. Such equipment is, at the time of writing, in the course of construction at the Ottawa Laboratory.

One of the first matters that will receive attention in the new kiln will be the determination of the cause and means of reducing the wide range in moisture content of the lumber after drying, which was very apparent in all of the tests carried out. If experiment shows that this shortcoming can be eliminated, the way is open to investigations that may eventually result in a series of schedules or recommended treatments for each of the commercial species in Canada.

This is assuming, of course, that other factors, outside of the process itself, prove favourable. These include initial costs of equipment, operating costs, suitability of the equipment itself to locale and for commercial operation in specific fields, and, in general, the factors that, in the final analysis, are responsible for the acceptance of any industrial process by industry. In this paper, no attempt will be made to assess these factors quantitatively, but rather, certain approaches will be examined. Final answers can only come with further research.

Initial Cost

Initial cost of equipment is of primary concern to industry. The cost of a high temperature kiln as compared to a kiln using conventional temperatures would certainly be, size for size, much greater. However, the output of a high temperature kiln may be as much as four times that of a conventional kiln of comparable size. The high temperature plant could thus be one-fourth the capacity, which materially affects the initial cost. This would have particular significance where a completely new industrial installation is being contemplated.

Table 1.—CONSUMPTION OF POUNDS OF STEAM PER POUND OF WATER EVAPORATED

Run	Species	Stock inches	Moisture content percent		Lbs. steam (equivalent to electrical energy consumed) per lb. water evaporated
			Initial	Final	
4	E. W. spruce	2	60	23	1.55
5	E. W. spruce	2	73	19	2.65
6	E. W. spruce	1	49	4	2.17
7	E. W. pine	1	113	10	1.76

Where kiln installations of a conventional type are already in use, the initial cost problem is, of course, a different matter. It would seem doubtful if the discarding of an installation in its entirety and the replacement of it with high-temperature kilns would ever prove an economic proposition—excepting in cases where the need for complete replacement is imminent. However, it may be found (particularly in the case of tile and concrete kilns) that modification alone would result in a satisfactory high-temperature kiln. Added insulation would be required in almost all cases, and the interior of the kiln might require resheathing with material especially resistant to corrosion. It might be necessary also to install internal fittings of aluminum to replace those made from iron or steel. In this connection it is to be noted that aluminum is already gaining favour with operators of conventional kilns. The adequacy of existing circulating and heating equipment would have to be considered and either replacement or modification undertaken.

Apart from the kiln itself, the problem of supplying the extra steam required would have to be faced. The use of electricity for heating is discussed later. In many plants in Eastern Canada, the steam required to heat kilns is "waste" steam, supplied at low pressure after it has performed its primary function of producing plant power. For high-temperature kilns, live steam over 75 p.s.i. is necessary. In those plants where no high pressure steam is in use, such pressures would require extra boiler capacity.

The feasibility of adapting existing loading and unloading arrangements and equipment would also have to be considered, and, of course, factors arising from the kiln site itself would be of primary concern.

Operating Costs

Because of safety regulations, qualified boiler room staff would be required to operate pressures necessary in high-temperature kilns; this would add to overhead costs. The degree to which the peak heating loads could be staggered and the degree of adroitness in handling the kilns would have a bearing upon operating costs. The desirability of a number of small kilns as opposed to one, or a few, large ones, is another question which poses itself; not only, of course, in connection with operating costs but as to initial cost as well.

As to handling the lumber before and after drying, and assuming the same volume of output, it would appear that the same loading staff and costs would apply to both high-temperature and conventional installations. The time required to load and unload charges would be the same, but, as drying time would be reduced with a high-temperature installation, certain adjustments would probably have to be made in handling arrangements.

Electricity might prove to be economically superior to steam when the over-all operating costs are being considered. The locale is, of course, an all-important factor. Steam would probably still be required for the humidification of the charge during the warming up period to prevent surface drying and to help establish conditions on the surface of the lumber that lead to satisfactory drying. This latter effect is only a tentative supposition. Steam may also be required for conditioning the lumber following drying; that is, for relieving the boards of undesirable stresses that may have developed during drying. Just what conditioning treatments may finally be proven to be necessary is, at the moment, an imponderable, though tests made at this Laboratory showed that conditioning may not necessarily be a long or overly steam-consuming process.

Only very wet, low-pressure steam is required for conditioning purposes. Such could be provided by a small electrical steam generator as used in some European installations, or by a

Figure 3.—Inspecting thermocouples used to measure temperatures within the charge during drying.

small boiler. The feasibility of using a fine water mist instead of steam should be kept in mind, and also the probability that in certain cases no external humidifying agent will be necessary during warming-up. The lumber charge may be sufficiently wet, that on being heated, it supplies all the humidity necessary to prevent any excessive surface drying. (All vents leading to atmosphere are, of course, kept tightly shut during the warming up period.) In two of the test runs, charges were satisfactorily "stewed in their own juice" in this manner. It is felt then that the problem of humidification when using electricity as a heat source is not a difficult one.

Tests have shown that drying may continue after the heat source has been removed. This is caused by the residual heat in the lumber itself acting to good advantage in a very well insulated kiln. Extension of the drying period in this manner may bear importantly on the reduction of drying costs.

Finally, there is the question of the relative drying efficiencies of conventional and high-temperature kilns. Data obtained in the Ottawa Laboratory's investigations support conclusions reached by several European investigators, that as a "drying machine" the high temperature kiln is likely to be the more efficient.

Results obtained during the course of the studies on the high temperature kiln drying of softwoods are shown in the Table 1. This will enable a comparison of the efficiency of the kiln and high temperature process with conventional kilns drying at low and medium temperatures.

Economic drying, as a goal, has not yet been striven for by the Ottawa Laboratory, and in Runs 5 and 6 the largest possible volume of air was introduced and circulated, and the heat wastage was at a maximum.

Consumption for softwoods in conventional kilns, under average conditions, per pound of water evaporated has been estimated at from 2.00 to 2.75 pounds of steam.

However, because of the scarcity of information, the above comparison is of uncertain legitimacy, but it serves to indicate that the high-temperature kiln will, in all probability, prove to be the more efficient tool, quality of product being equal.

General

It would seem that high-temperature kiln drying would be most suitable for the medium-to-small woodworking plants, where fluctuating requirements mean that small loads must be dried with as little delay as possible. From this point of view, one or two small high-temperature kilns might prove an economical adjunct to existing seasoning facilities. This presupposes that this process will prove effective for the drying of hardwoods, green from the saw—which from present knowledge is by no means certain. Experience in Europe has shown that serious difficulties may be encountered in this application of the process, and, while Ottawa Laboratory exploratory tests in this regard gave fairly satisfactory results, they were not as promising as were the tests with the various species of softwoods.

The problems connected with this new field of kiln drying are many and some are complex. Ottawa Laboratory investigations are, as yet, not far beyond the initial stages. Other investigations, either directly or indirectly connected with high temperature seasoning are in progress in the United Kingdom, the United States, and Australia.

Research in kiln drying is, at best, time consuming, and this specific field is no exception. The number of variables involved—species, thickness of boards, circulation rate, temperature, humidity, sticker thickness, to mention only the most fundamental—tend to render the design of experiments complicated and the assessing of results difficult. Each test run involves many days of work over and beyond the time during which the kiln is in actual operation. To obtain a dependable record, a large number of test runs is required.

In addition, investigations will be necessary to determine the effect of high temperature drying on the properties of the wood, and on the fitness of high-temperature-dried wood for certain uses. These and similar considerations will necessarily bear on any decisions to be made.

Thus it may be some time before the Ottawa Laboratory has sufficient data upon which to base positive recommendations regarding the use of high temperatures in the drying of lumber. In the event that the advantages of high temperature drying become apparent, this method of drying will have to be carefully scrutinized in the light of the many factors involved, some of which are indicated in this paper.

Of these "advantages", speed of drying comes first to mind. Fast drying would make for flexibility in production, an important asset, especially to the smaller manufacturer. However, speed may be a mixed blessing, giving rise, as it would, to organizational problems and perhaps to power difficulties. The relatively smaller space required to house the fewer high temperature kilns necessary would be an important factor, particularly in smaller plants. Fewer kilns could also result in lower maintenance costs.

Research will provide information regarding the practicability of the process, specific recommendations may follow, and correct techniques may be developed and publicized. In the last analysis, however, the decisions as to which type of kiln is best suited to his own conditions must rest with the individual operator in the light of factors peculiar to his own circumstances —his organization, plant, plant site, and requirements.

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The Effect of Time, Temperature, and Relative Humidity on the Relief of Casehardening Stresses[1]

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Indications were obtained on the relative effect of time, temperature, and relative humidity on the relief of casehardening. Best results were obtained when a combination of moderate relative humidities and high temperatures were used. In some cases elevated temperatures alone rendered stock stress free, presumably by plasticizing action for the most part.

Introduction

WOOD, UPON DRYING, is subjected to highly complicated internal stresses. Methods have been devised for relieving these casehardening stresses in lumber at the end of the kiln-drying process. However, there is an unnecessarily large amount of casehardened material on the general market despite the fact that many dry-kiln operators relieve these stresses. Casehardened material is not to be frowned upon except where the material is reworked, such as when it is resawn, dressed more on one side than the other, carved, or run over a molder or router.

If wood is to maintain its place in the field of furniture and interior trim materials, more care must be exercised in providing stress-free stock for the market.

The unnecessary expenditures and wasting of materials show that there is a definite need for further research on the formation of stresses and their relief. Therefore, the purpose of this study was to delve into the relative effects of the three factors (time, temperature, and relative humidity) involved in the relief of casehardening stresses.

Development of Casehardening Stresses

Wood begins to shrink when the cell cavities lose their moisture and the water starts leaving the cell walls. This condition of no water in the cell cavities but with the cell walls still holding all they can is called the fiber saturation point. In most species, the fiber saturation point is between 27 and 30 percent moisture content (5).[2]

As green lumber dries, a moisture gradient is quickly established. When the outermost surface dries to a moisture content in balance with the surrounding atmospheric conditions, the surface has reached equilibrium moisture content (1). When this equilibrium moisture content value is lower than the fiber saturation point, shrinkage attempts to take place. The fibers attempt to shrink in proportion to the reduction in moisture content below the fiber saturation point. The movement of moisture from the central or core section of the piece is slower than the rate of moisture evaporation from the surface; therefore, a definite moisture gradient occurs at the outset of drying. Since the drying is not uniform throughout the thickness of a piece, the surface fibers are restrained from shrinkage in accordance with the lesser moisture loss below the fiber saturation point by the wet interior cells, This restraining action causes the surface or exterior fibers to be stressed in tension with an equal compressive action on the interior fibers. The unit stress, at this period of drying, however, is greater in the tension-stressed zone due to the unequal volumes of fibers being stressed in each zone. Since the moisture content gradient is steepest during the early stages of drying, the greatest unit of stress in tension is also present then (6).

If these tension forces in the surface zone exceed the proportional limit (in tension perpendicular to the grain) of the wood, the cells in this zone will become set in this stretched or expanded condition. Despite the range of relative humidity control possible in a lumber dry kiln, it is virtually impossible to keep the drying stresses within the proportional limit so that a set condition does not take place. According to an example cited in ANC Bulletin 21 (11), even the mildest of kiln conditions will cause the surface zones of a piece of lumber to be stressed in tension beyond the proportional limit. Further, if the tension stresses exceed the maximum load, such drying defects as end checks, surface checks, and honeycomb will result.

As drying progresses, the zone that is stressed in tension moves inward toward the center of the piece. Since the surface zone has developed its set in the expanded condition, however, it resists the shrinkage in the inner zones. Thus, the surface fibers first undergo a state of tension stress, become set, then switch to a state of compression stress. Conversely, the inner zones will first be stressed in compression and then change to a state of tension stress. Due to the lower unit stress in compression, set from this type of force is much less common than the set that is developed from tension stress.

Tiemann (8) suggests that the phenomenon of set in wood appears to be an internal slipping of the cellulose molecular chains one on another within the crystallites, rather than a rearrangement of the molecule. Set wood,

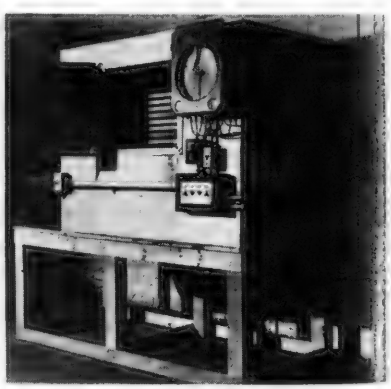

Figure 1.—Experimental humidity chamber.

[1] This paper is a condensation of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Wood Technology, School of Natural Resources, Univ. of Mich.

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[2] Numbers in parentheses refer to literature cited at end of paper.

Figure 2.—Specimen-measuring gage.

however, will shrink and swell as if had no set, except that the initial reference or starting point is different. This would indicate little rearrangement of the molecular structure in relation to the size of the intercellular areas, which are directly responsible for the shrinkage and swelling of wood.

Wood will act as a plastic under prolonged strain, and permanent deformation may result, even though the forces involved were never great enough to strain the wood beyond its elastic limit. This plastic deformation varies more or less with temperature. Brown, Panshin, and Forsaith (2) indicate that set in wood resulting from drying probably involves plastic deformation as well as permanent deformation from stresses beyond the proportional limit. The phenomenon of set in wood remains apparently to be satisfactorily explained. However, there is evidence that the degree of set will diminish with time alone.

If a piece of dried lumber shows evidence of set, it is termed casehardened. This can be concluded to be the normal behavior of wood when it dries. Casehardened lumber is unsatisfactory if it is to be reworked, as it usually cups, bows, or distorts in other ways. Fortunately it is possible to relieve or balance these stresses at the end of the drying period in a lumber dry kiln.

The relief of the stresses and set in casehardened lumber is accomplished essentially by the addition of moisture to the exterior surfaces of the lumber. This causes the exterior fibers to swell thereby compressing while the inner zones are being subjected to tension stresses. Theoretically, the stretching of the inner zone plus the compression in the outer zone causes all portions to assume equal dimensions when a uniform moisture content is reached.

It is possible to wet the exterior fibers too much during the conditioning treatment, thereby causing a phenomenon termed reverse casehardening. This is caused by the outer surfaces developing an excessive amount of compression set. When the lumber assumes a uniform moisture content, the conditions will be reversed from those of casehardened material. The seriousness of this condition should never be overlooked for the lumber is unsatisfactory for uses that demand further manufacturing. There is no economical method of relieving reverse casehardening.

With the knowledge that casehardened lumber can be made stress free, a new approach may be taken for devising future kiln drying schedules. Rapid and accurate means of measuring the stresses is the current stumbling block. Rietz (7) suggests the possibility of reducing drying time appreciably if schedules can be based on the stresses acting in the wood and their magnitude. Lower relative humidities may be used during drying as long as the resulting stresses do not exceed the maximum strength values (perpendicular to the grain) of the wood, thereby causing failures. Tiemann (8) states: "It is not the moisture content itself, nor the time the lumber has been in the kiln, that is the prime consideration for the determination of when to change the kiln conditions. What really counts is the amount of stress existing in the lumber."

Indications point toward the use of stress and set proportions for the determination of future drying schedules; ultimately conditioning may become more important. In the conditioning treatment, it has been proven many times that moisture is of utmost importance; but what of the temperature and time elements involved?

An attempt has been made in the study reported here to determine the relative effects of the three factors (time, temperature, and relative humidity) involved in the relief of drying stresses and sets.

Apparatus

The material used in the study in a standard lumber dry kiln with reversible forced air circulation. This kiln has a capacity of 2,000 board feet. Considerable baffling was necessary to insure uniform air circulation throughout a small load of 108 boards.

An experimental conditioning chamber (Fig. 1) was designed and constructed for the various conditioning treatments. This unit had a load space that measured 24 by 21 by 20 inches. Circulation, which could be varied from 180 lineal feet per minute minimum to 400 feet per minute maximum, was supplied by a 12-inch internally mounted fan. Controlled temperatures of from 90° to 200° F. were furnished by a bank of six 75-watt electric strip heaters. Controlled relative humidity conditions could be varied from 0 to 100 percent by means of an external steam-spray system. Uniformity of circulation was enhanced by two 4-cubic-foot plenum chambers on each side of

Table 1.—THIRTY-SIX EXPERIMENTAL CONDITIONS

Treatment	Specimen No.	Dry bulb temperature °F.	Wet bulb temperature °F.	Relative humidity percent	Equilibrium moisture content percent	Time Hr.
1	1–3	150	115	34	5	12
2	4–6	150	115	34	5	18
3	7–9	150	115	34	5	24
4	10–12	150	115	34	5	30
5	13–15	150	126	50	7	12
6	16–18	150	126	50	7	18
7	19–21	150	126	50	7	24
8	22–24	150	126	50	7	30
9	25–27	150	133	62	9	12
10	28–30	150	133	62	9	18
11	31–33	150	133	62	9	24
12	34–36	150	133	62	9	30
13	37–39	170	135	40	5	12
14	40–42	170	135	40	5	18
15	43–45	170	135	40	5	24
16	46–48	170	135	40	5	30
17	49–51	170	146	55	7	12
18	52–54	170	146	55	7	18
19	55–57	170	146	55	7	24
20	58–60	170	146	55	7	30
21	61–63	170	154	67	9	12
22	64–66	170	154	67	9	18
23	67–69	170	154	67	9	24
24	70–72	170	154	67	9	30
25	73–75	190	156	43	5	12
26	76–78	190	156	43	5	18
27	79–81	190	156	43	5	24
28	82–84	190	156	43	5	30
29	85–87	190	168	60	7	12
30	88–90	190	168	60	7	18
31	91–93	190	168	60	7	24
32	94–96	190	168	60	7	30
33	97–99	190	175	71	9	12
34	100–102	190	175	71	9	18
35	103–105	190	175	71	9	24
36	106–107	190	175	71	9	30

the load area. Temperature and relative humidity were both automatically controlled by a "Taylor Fulscope" controlling instrument.

All moisture content sections were dried in a forced-draft drying oven set at 212° F.

A gage was constructed with which to measure the stress specimens to 0.0001 inch accuracy. This gage (Fig. 2) consisted of a 5/16-inch steel plate base, a center flat bed rest, a perpendicular reference plate, a bar slide, and a dial gage. The reference plate was fastened to the base plate approximately 4.7 inches from the dial indicator. The bar slide, which activated the dial gage, offered a flat bearing surface rather than a radius to rest against one end of the specimen being measured. This reduced the variability of the gage readings due to surface imperfections of the specimens.

Material

Clear yellow birch (*Betula lutea*) that had been air dried for 1 year was selected as the test material. These pieces, which were of random lengths and widths, were cut to 5-foot lengths and reduced in width to approximately 5 inches.

Six kiln samples, approximately 5 inches wide and 30 inches long, were prepared as the guides during kiln drying. These samples, together with the rest of the material, were end-coated with 3 coats of Angiers end-coating material to retard end-grain drying.

The kiln schedule used on this air-dried yellow birch was the Forest Products Laboratory schedule T8-C4 (9). The original average moisture content, as shown by the ovendry tests, was 16 percent. The charge showed an average of 4.8 percent when it was removed from the kiln.

The material was stored in an equalizing room operating at a 5 percent equilibrium moisture content condition with a 75° F. temperature for 45 days, during which time it became equalized to approximately 5 percent moisture content.

Following this equalizing period, the 5-foot boards were cut into 2 end-matched 18-inch test specimens (Fig. 3) and then returned to the equalizing room after end-coating. These end-matched test specimens were labeled "U" for untreated and "T" for treated. They were numbered from 1 to 108 by a random selection to discount any bias as to the selection of pieces. There were 108 "T" specimens, which were given various casehardening relief treatments, and 108 "U" specimens, which acted as the matched controls or no treatment group.

Testing Procedure

Due to limitations of the experiment, 36 conditions were selected to study the various effects of time, temperature, and relative humidity on the relief of drying stresses. The conditions selected are listed in Table 1.

Twelve of the "T" specimens were placed in each of the nine kiln runs. At each specified time interval during a run, 3 specimens were removed and designated as 1 treatment. As the specimens were removed, blank pieces of the same dimensions were put back in the load to prevent differences of air circulation on the remaining pieces. Following removal from the kiln, three sections were cut from each test board (Fig. 3). These were: (1) a moisture-distribution sample, (2) a visual-stress sample, (3) and a measuring-stress sample. Similar sections plus a measuring blank were cut from the matched, untreated "U" specimen that had been stored in the 5 percent equalizing room.

The moisture-distribution sections were cut, weighed, and labeled, then put in the oven to dry. This green weight and the ovendry weight obtained permitted the calculation of the moisture distribution after the conditioning treatment. Examples of some of these data are given in Table 2.

The visual-stress sections were cut as shown in Figure 3 and placed in the equalizing room to allow the prongs to come to a uniform moisture content. The measuring specimens were also placed in the equalizing room after cutting and marking for identification.

This procedure was followed for the nine runs. All of the measuring-stress specimens were removed from the equalizing room to the humidity chamber after 1 week. They were equalized in this chamber at conditions of 140° F. and 5 percent equilibrium moisture content. This was done in order to avoid the possible dimensional variance caused by moisture content differences between the specimens. After this equalizing period, the samples were removed to the 5 percent equilibrium moisture content room, and measured. Measurements were taken of the two exterior sections (shell or surface zones) and the center section (core).

Photographs were taken of the visual-stress sections after they had been in the equalizing room for a minimum of 2 weeks.

The measuring blanks, section D (Figure 3) of the untreated specimens were kept in the equalizing room approximately 4 weeks before they were measured. An average measurement was taken. This measurement was considered as the average width of the test specimen prior to any relief treatments.

In casehardened lumber, it is known that the shell or surface zone is in a state of tension set. Therefore, if these zones are removed from the piece, they will increase in length. The core or central section will shorten upon removal if any compression set is present. The difference in length of these sections can be used as a measurement of the set present within the stock. In reverse casehardened material, the core section will exhibit greater dimensions than the surface zones, assuming permanent deformation has occurred.

Measurement differences were used as a basis of quantitatively evaluating the degree of casehardening or reverse casehardening present in the treated and untreated specimens. This procedure made it possible to compare the effectiveness of the various treatments by noting the change in differences of the core and shell measurements of the treated and untreated specimens. The degree of casehardening is expressed as a percentage of change in dimension of the core and shell zones, as based on the matched, untreated dimension.

An example of the calculations is given to clarify the method.

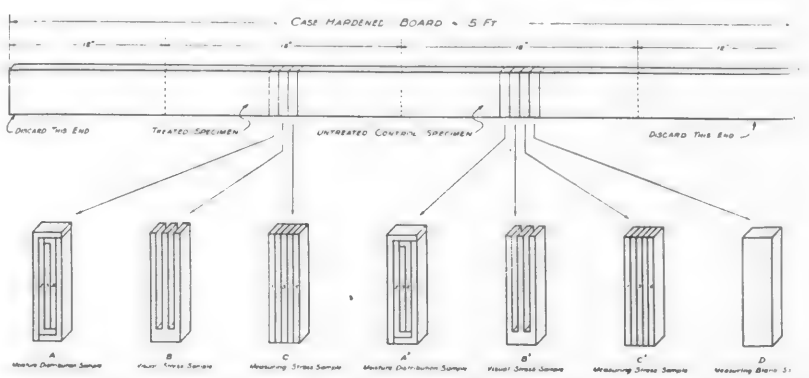

Figure 3.—Sampling technique.

reat-nent No.	Sample	Measure-ment inches	Differ-ence inches	Degree of case-harden-ing percent
1.	IT–1 (Shell)	4.7420		
	IT–5 (Shell)	4.7436	0.0058	0.122
	IT–3 (Core)	4.7370		
	IB[1]	4.7400		

[1]Sample IB is the measuring blank section cut from the untreated sample.

$\frac{4.7420+4.7436}{2}=4.7428$ (average shell dimension)

$4.7428-4.7370=0.0058$ (difference between average shell and core)

$\frac{0.0058}{4.7400}\times 100=0.122$ percent (degree of casehardening)

The three graphs (Figures 4, 5 and 6) illustrating the relative effects of time, temperature, and relative humidity were plotted using the average degree of casehardening percentages for each treatment.

Discussion of Results and Conclusions

Time and Temperature: It has been stated previously that moisture is known to have a decided effect on the relief of set and internally stressed lumber. It is obvious that unless the relief is casehardening is instantaneous, time must exhibit some effect also. The effect of temperature cannot be proven as simply as that of time. However, in Figure 4, the effect of temperature is clearly illustrated. The equilibrium moisture content conditions in the chamber and the moisture content of the stock were both 5 percent as the start of the treatment. Therefore, there was no addition of moisture to the outer surfaces of the material during the treatment. Any reduction in the magnitude of casehardening must be attributed to either time, temperature, or both. An increase in the temperature from 150° F. to 170° F. brought about greater relief and in a shorter period of time. Increasing the temperature to 190° F. further increased the removal of the stresses in an even shorter time than had been required for the 170° F. condition. These curves show that temperature plays an important role in effecting the removal of casehardening set and stresses. From the results, it cannot be definitely stated that a given increase in temperature will increase the amount of relief a certain percentage. It does appear, however, that the total increase in relief at any of the time intervals appears to be proportionate to the increase in temperature. If this were true, an additional rise of 20° F. in temperature would show a curve dipping below the abscissa or balanced stress line. If this occurred, it would prove that temperature alone can cause reverse casehardening and is also causing set within the piece.

Table 2.—EXAMPLES OF MOISTURE DISTRIBUTION FROM SOME OF THE TREATED AND UNTREATED SAMPLES

Sample No.	Section No.	Moisture content percent	Sample No.	Section No.	Moisture content percent
1T	1[1]	5.0	1U	1	4.7
	2[2]	5.2		2	5.2
	3[3]	5.1		3	5.4
20T	1	6.3	20U	1	5.2
	2	6.0		2	6.8
	3	5.7		3	5.9
40T	1	5.7	40U	1	5.5
	2	6.5		2	6.8
	3	6.7		3	7.2
60T	1	6.3	60U	1	5.0
	2	6.0		2	5.7
	3	5.8		3	5.9
80T	1	5.1	80U	1	4.8
	2	5.3		2	5.4
	3	5.2		3	5.5
100T	1	8.1	100U	1	5.2
	2	7.3		2	6.1
	3	6.4		3	6.4

[1]Outer zone.
[2]Inner zone.
[3]Core.

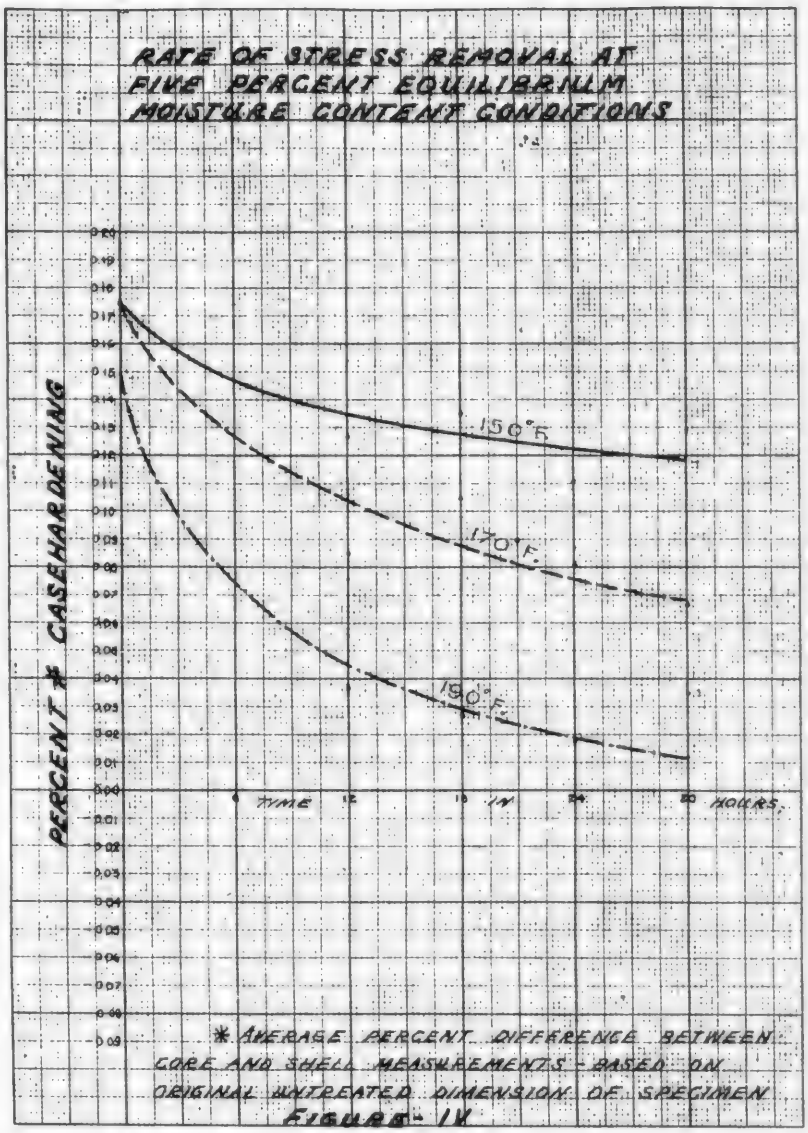
RATE OF STRESS REMOVAL AT FIVE PERCENT EQUILIBRIUM MOISTURE CONTENT CONDITIONS
PERCENT * CASEHARDENING
150°F.
170°F.
190°F.
TIME IN HOURS.
* AVERAGE PERCENT DIFFERENCE BETWEEN CORE AND SHELL MEASUREMENTS - BASED ON ORIGINAL UNTREATED DIMENSION OF SPECIMEN
FIGURE - IV

Figure 4.—Rate of stress removal at 5 percent equilibrium moisture content conditions.

Therefore, the possibility of relief by thermal expansion of the outer surfaces caused by the higher temperatures should not be overlooked. Any expansion of this nature, however, would have to be of sufficient magnitude to cause the straining of the wood beyond its proportional limit. Stresses that would arise from thermal expansion would be minor compared to those developed from moisture changes. There seems then to be another cause for this relief brought about by higher temperatures, namely, the plasticizing effect of temperature on wood. A temperature of 350° F. (8) is high enough to plasticize hardwoods so that they can be molded into various shapes. The increase in relief that follows an increase in temperature could be caused by the wood becoming more plastic. Greenhill (3) found that at a temperature of 180° F., the tension strength and modulus of elasticity perpendicular to the grain were reduced from 1/3 to 1/2 the values for corresponding properties at normal temperatures. This reduction was found to be greater in stock with a high moisture content. If the reduction in strength was sufficient for the maximum temperature rise of 120° F., a relatively low stress could cause the wood to be strained beyond its proportional limit and the relief could be a cause of thermal expansion. The relief of casehardening by temperature then can be assumed to be caused by a combination of the thermal expansion and plasticizing actions.

Figure 4 shows the progress of relief with temperature, but in none of the tests did the cores and shells obtain equal dimensions. This would indicate that the pieces were still casehardened. The amount of casehardening present, as shown by the visual inspection sections (of those treated at 170° and 190° F. at a 5 percent equilibrium moisture content), was so minute they appeared stress free. The pieces treated at 150° F. and 5 percent equilibrium moisture content still showed some casehardening on the visual sections, denoting that the temperature was not high enough for relief. This assumption is made on the basis that the tendency of the curves is to become asymptotic after 30 hours of treatment.

The results, then, disclose the possibility of relief of casehardening by temperature alone. A kiln charge could be allowed to cool and then subjected to a high temperature for stress relief. High temperatures will reduce the strength properties (10), but the reductions are not appreciable at the temperatures used except after long periods of exposure. Therefore, it seems that this method warrants further investigation as to the possibilities of commercial use.

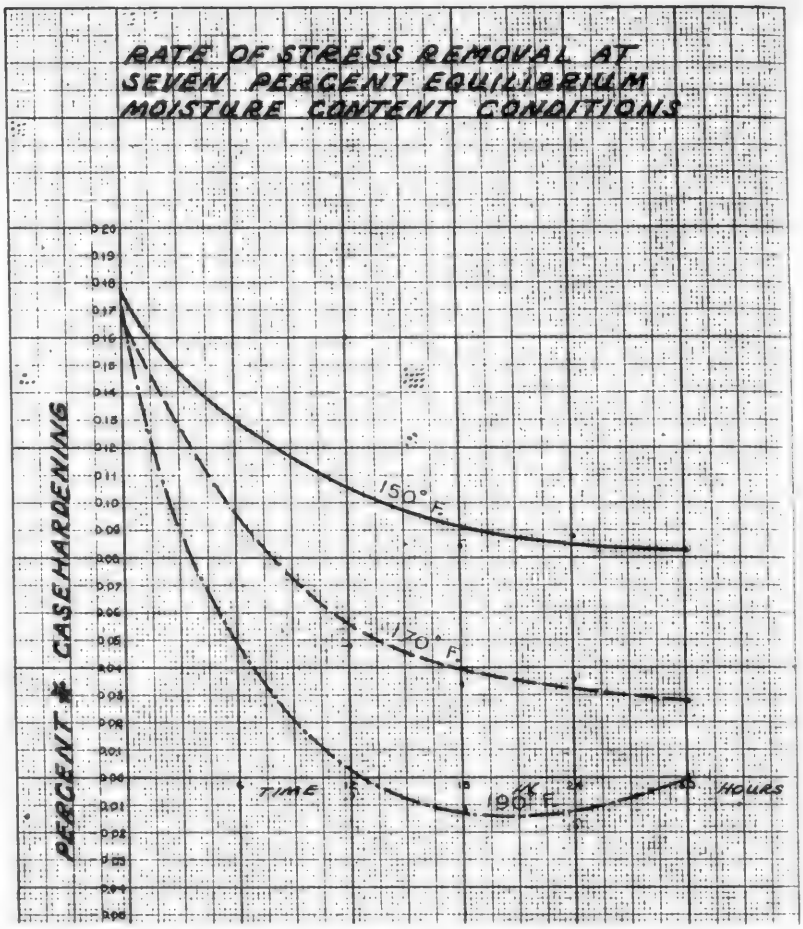

Figure 5.—Rate of stress removal at 7 percent equilibrium moisture content conditions.

Relative Humidity: The effect of relative humidity on the relief of casehardening is illustrated in Figures 5 and 6. Comparison of these curves with those of Figure 4 show that any increase in relief, beyond that attributed to temperature, must be caused by the action of moisture on the surface zones of the material. With an increase of relative humidity, the time required for relief was greatly decreased. Reverse casehardening was also found to occur with the higher relative humidities. At the 9 percent equilibrium moisture content condition, reverse casehardening was present at every temperature condition on visual inspection. However, this phenomenon was not indicated by the core and shell measurements of the 150° F. temperature group. The difference in reaction of the visual and measured sections can be explained by the fact that the sudden addition of moisture acts only on the surface of the piece. Thus, these surface fibers may undergo a state of severe compression set. The volume of fibers that are affected is much smaller than the volume of fibers that do not take on additional moisture. It was observed that the central portions of a board could be casehardened with the exterior zones exhibiting reverse casehardening. Henderson (4) has illustrated this condition which occurred in casehardened lumber that had been steamed for 1 hour. Additional steaming might relieve the central portions of the piece, however, the surfaces would probably remain in a reverse casehardened condition. It appears that the addition of moisture alone is not a good practice for relief of stresses since the amount of moisture added to the surface increases the possibility of reverse casehardening.

The curves that entered the reverse casehardening range, below the zero-difference line, all showed a minimum point after a certain period of time. The time factor for this occurrence varies with the temperature involved. Reverse casehardening was actually relieved in some instances as the curves indicate. Figures 5 and 6 illustrate this trend. This relief could be from two sources. One could be from the development of stresses as the moisture

moves inward toward the center of the piece. The shell is under a state of compression set and tends to resist the expansion of the core or central zone. As the core takes on more moisture the stresses increase, and, if great enough, they will counteract the compression set in the outer zones, leaving the lumber stress free. Some of the moisture distribution data collected show a moisture gradient pattern that indicates this could actually occur. The second source of relief of reverse casehardening could be the temperatures used. The specimens treated at 190° F. and 9 percent equilibrium moisture content conditions appeared to be fully relieved after 30 hours, while those treated at 170° F. with the same equilibrium moisture conditions still showed reverse casehardening after 30 hours.

Relative humidity alone does not appear to be a satisfactory means for the removal of stresses. However, a combination of high temperatures and a moderately elevated relative humidity (190° F. with a 7 percent equilibrium moisture content) showed their effect at all of the time intervals studied. The superiority of this method (which is closely associated with present practice) over one of temperature alone would depend on the economics involved pertaining to time and heat.

In a single study on the relief of casehardening (with temperature and relative humidity constant) it was found that some relief occurred during an 8-week period. This relief can be attributed to time. The general belief is that casehardening would never become completely relieved by the action of time alone. The function of time in this study is shown in Figures 4, 5 and 6. The curves that did not cross the abscissa appeared to become asymptotic. However, those that intersected the abscissa exhibited a minimum point. The curves ascended from this minimum point toward the abscissa and appeared to show a trend toward a second intersection with the zero-difference line. If the curves rose above the zero-line, it would mean that the stock had passed from a casehardened condition to one of reverse casehardening and then returned to a casehardened condition because of the addition of moisture. This pattern does not appear to be logically correct.

If additional time periods had been included in the study, more complete information might have been collected. Perhaps, over longer periods of treatment, the stock would have been fully relieved under all conditions. It would have been interesting to note the effect of time on the relief of casehardening. Increasing the time, in all instances, would have given much additional and valuable information.

Summary

This study gave indications of the relative effects of time, temperature, and relative humidity on the relief of casehardening.

It is felt that the time element should have been extended for longer periods using the same intervals. Time definitely is an important factor in the relief of stresses. The exact magnitude of stresses relieved due to time was not determined, its interaction with relative humidity and temperature, however, was of obvious importance.

In some instances, temperature alone rendered the stock stress free. Where temperature was not acting alone, it was an important factor. The effect of temperature on the relief of stresses or set in casehardened material is attributed to its strength-reducing and plasticizing qualities plus thermal expansion.

Relative humidity, like temperature, may relieve casehardening by itself. If relative humidity conditions are too severe, reverse casehardening will occur. Lumber in this state is as unsatisfactory as if it were casehardened. Best results on the relief of casehardening were obtained when a combination of moderate relative humidities and high temperatures were used. In the high temperature and relative humidity ranges, reverse casehardening was relieved in some instances. In others, a definite trend toward relief was established.

Various questions that have arisen from this study warrant investigation. Some of these questions are:

1. Is the relief of casehardening by the use of high temperatures applicable for commercial use?

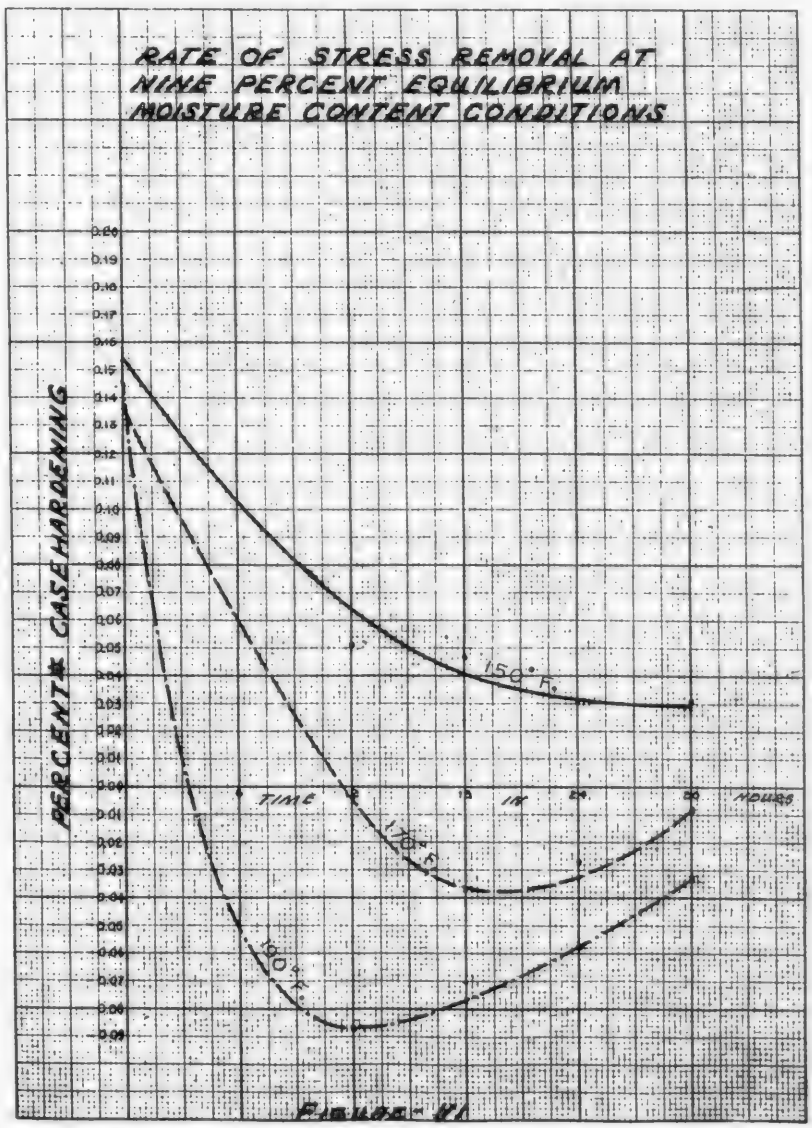

Figure 6.—Rate of stress removal at 9 percent equilibrium moisture content conditions.

2. Is low temperature relief possible?

3. What effect does time have on the relief of casehardening without the interaction of temperature and relative humidity?

4. Is there a possible short-time method for relieving reverse casehardening stresses?

5. Is stress-free lumber better (from a mechanical-properties viewpoint) than casehardened stock?

6. To what extent are the strength properties, perpendicular to the grain, effected by temperature and relative humidity conditions?

Many of these questions, and others, could be answered by an enlarged study set up with a sound statistical framework. This study, was limited and was largely exploratory. The results obtained and conclusions drawn should not be extended beyond the scope of the study. However, it is felt that definite trends were established that might apply under similar conditions.

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Discussion

Ray Rietz (U. S. F.P.L.): I would like to suggest definition of casehardening as follows: "Condition of stresses in dry lumber caused by set resulting from shrinkage stresses."

A. Knauss (U. S. Forest Service): Did all pieces start at 5 per cent MC, equalized?

Fred E. Dickinson (University of Michigan): Yes.

Mr. Rietz: At what temperature?

Mr. Dickinson: 75° F.

John Yavorsky (New York State College of Forestry): Please discuss problem of variation where E.M.C. is 5 per cent.

Mr. Knause: If in operating kiln we could get equilibrium of moisture before drying we could do better. Should use temperature to plasticize wood to relieve stresses.

John Devine (Moore Dry Kiln): Would this relief be result of thermal action?

Mr. Knause: No. Two actions. Plasticizing more important than thermal action.

Mr. Devine: What would be thermal expansion?

Mr. Knause: Greater than some metals, less than others.

Mr. Rietz: Thermal expansion has to be associated with temperature gradient, between inside and outside, which is very short at 150 degrees.

Comment: *Mr. Rietz:* This paper suggests that we need more information on casehardening.

Question:

Mr. Churchill mentions that some of the percent case-hardening curves of Figures 5 and 6 show a rather illogical pattern in that a return to the zero level or even re-entrance into the conventional case-hardened condition from that of reverse case-hardening is indicated. I do not wish to compound his difficulties, but I wonder if he would care to theorize as to whether these curves would return to zero asymptotically or possibly even oscillate about the zero axis.

Mr. Churchill: The appearance of the curves indicates that in some cases their course would be one of an oscillating nature. However, I know of no reason for such action. Ultimately, the curves would stabilize within an extended time period and parallel the abscissa.

H. B. Gatslick (New York State College of Forestry): Were internal temperatures determinations made in the wood samples? Were any temperature gradient studies made for samples in conjunction with this study . . . I am thinking in terms of possible temperature gradient effects from increased E.M.C. conditions.

Mr. Churchill: Due to the limitations of this study, no temperature readings were made either on the surface or inside the test samples. However, prior to the conditioning treatments, the temperature of the samples was 75 degrees F. and, of course, experienced a sudden increase in temperature with accompanying thermal expansion when subjected to the higher temperature treatments.

Alleviating Bow and Crook in Southern Yellow Pine Dimension With Chemicals

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A study was made to find a practical way to alleviate bowing and crooking of southern yellow pine dimension, exclusive of lamination. Fifty-two hundred pieces of No. 2 grade 2-by-4 lumber eight feet long were involved in the treatment. Nine chemical compounds and two water proof papers were evaluated after storage and exposure periods at retail yards in Houston, Austin, Dallas, and Lubbock. An analysis of eight specific tree growth and lumber manufacturing characteristics reveals that changes in manufacturing techniques will probably be required before any appreciable reduction in the amount of bowing and crooking can be obtained. This action would be required in addition to the use of a chemical compound for stabilizing purposes.

Introduction

SOUTHERN YELLOW PINE dimension, long established as a superior wood for construction, and once held in high esteem by architects, contractors, and home owners has lost much of its prestige in a relatively short period of years. This is evidenced by the high degree of sales resistance to southern yellow pine, the increasing inroads being made by Douglas-fir on markets once held exclusively by southern yellow pine and by the pine producers' related concern because of the competition.

The perplexed reaction of reputable lumber companies to large scale shipment rejects is understandable. It is true that many of the producers have improved their over all operations. Many have dismantled old, worn out kilns and installed modern kilns. Operators have been trained for the full-time job of kiln operation. Yet, in spite of these efforts, there has been not only a higher incidence of crooked pieces but, to the dismay of the industry as a whole, sales resistance has also increased. The problem facing the industry deals with the large scale bowing, crooking and warping of lumber during the drying process, after shipment to retail yards, storage in the bins and finally, after use in construction.

One would suspect that this sudden and erratic behavior of southern pine lumber mentioned above was beyond the control of the manufacturer. As a matter of fact, it largely was. Paul and Sweet[1] state, "From one point of view, the situation in which the industry finds itself is due to the breakdown of the normal economic and industrial controls during the upset supply-demand conditions growing out of the war. From another point of view, however, the war conditions merely hastened along a situation that would have been more or less inevitable anyway, since it was associated with a replacement of former virgin timber stocks by second growth; a situation that calls for new controls, which may take considerable time to put into effect."

Past and Current Efforts to Solve Problem

Prompt action on the part of the industry through individual company effort and also through the Southern Pine Association was initiated. Efforts were made to win back consumer confidence through the application of recommended control measures and by introducing a new type of 2-by-4 lumber on the market.

Paul[2] showed that lumber cut from second-growth southern yellow pine containing fewer than 4 rings per inch would exhibit abnormally high longitudinal shrinkage, causing twisting, bowing and crooking. Consequently, the grading rule for No. 2 pine dimension was improved by the requirement that all pieces of this grade have "Not less than 4 rings to the inch".

Another vitally important measure was taken by the Southern Pine Association to improve the structural value of the No. 2 grade. O'Brien[3] reports that; "During World War II FHA developed tables of joist sizes for various spans based upon the same principles which are used in all structural values of the different grades and species".

In August of 1951 the Southern Pine Inspection Bureau of the Southern Pine Association initiated a survey through the members of their inspection staff. This survey was designed to cover crooked dimension handled on certificate, claim, and mill inspections. Information according to six classifications was taken on all pieces that were No. 2 in all respects except for excess crook. These classifications were as follows:

1. Pieces showing 4 rings per inch on one end only.
2. Pieces showing less than 4 rings per inch on both ends but otherwise of No. 1 quality.
3. Pieces showing compression wood. (Pillow[4] summarizes the role compression wood plays in causing bowing and crooking.)
4. Pieces showing the pith for all or part of its length.

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[1] Paul, Benson H. and Sweet, Carroll V. "Quality Control in Manufacture of Lumber from Second Growth", U. S. Forest Products Laboratory. Presented at Southwest Wood Products Conference, Lufkin, Texas, January 21, 1949.

[2] Paul, Benson H. "Reducing Bowing and Crooking of Lumber Cut from Second Growth Southern Yellow Pine". U. S. Forest Products Laboratory. Southern Lumberman, January 1, 1938.

[3] O'Brien, W. H. "The Present Market Outlook for Southern Pine Lumber and Dimension". Southern Pine Association. New Orleans, Louisiana.

[4] Pillow, M. Y. "Compression Wood Cause of Bowing and Twisting". U. S. Forest Products Laboratory. Wood Working Industries, November, 1930.

5. Pieces showing 4 rings on one or both ends and not showing pith but showing part of the fast growth immediately adjacent to it.
6. Pieces not showing any of the foregoing characteristics.

The results of this survey were summarized and were quite effective in pointing to the characteristics inherent in a piece of dimension which were causing excessive crook.

In the field of industrial effort to prevent or alleviate crooking and bowing, various measures were put into practice which were thought to be of practical value. Piling 2 by 4's and 2 by 6's on edge, both for air seasoning and kiln drying, is being resorted to with some small degree of success. One small 2 by 4 mill makes a practice to "box heart" all pieces cut from the center of the log instead of splitting a 4¼ by 4¼ cant through the pith. Another mill experimented with the idea of drying green 4 by 4's and then resawing to 2 by 4's at the planer. All of these practices conceivably are of some help though, admittedly, to a limited degree. All are aimed primarily at overcoming the effects of sawing practices and fail to recognize other causes for bowing and crooking. The causes are inherent in the individual piece and are due primarily to the character of a single type of wood tissue or to combinations of types of wood tissues causing abnormal and differential shrinkage. Log selection and modified cutting practices will reduce bowing and crooking to a minimum. By log selection is meant the actual choosing of the logs from which to cut dimension lumber.

Because of the economic limitations that would arise from cutting dimension lumber solely from selected logs, it was reasoned that perhaps some degree of stabilization could be obtained through the use of commercially available chemicals known to the trade as either wood sealers, water repellents, or stabilizers. By eliminating the most serious causes of bowing and crooking through proper log selection and improved sawing practices, and then chemically treating the dimension resulting from these improvements, positive steps could then be taken to improve the quality of southern yellow pine dimension.

Purpose and Scope

The purpose of this study, therefore was to find a practical means to alleviate or prevent bowing and crooking of southern yellow pine dimension, exclusive of lamination. Fifty-two hundred No. 2 2 by 4's eight feet long, half of which were air-dried and half kiln-dried, were utilized in the experiment. The 2 by 4's were obtained from 7 sources typical of the southern pine industry in Texas. Nine commercial chemicals and 2 commercial water-repellent papers were included in the treatments. The remaining 2 treatment groups involved no treatment — the controls. One retail yard each in Houston, Austin, Dallas, and Lubbock, was chosen as a storage and exposure area for testing the effects of varying equilibrium moisture contents on the treated and untreated dimension. In Austin and Houston, the 2-by-4 lumber was piled in the customary fashion in bin space provided by the retail yards. In Dallas and Lubbock, storage sheds were constructed to simulate normal retail yard storage since it was impossible to obtain storage space at the time from the cooperating lumber companies.

The lumber was stored for 8 weeks in the bins after which a study was made of the behavior of each piece. The lumber was then placed flat on the ground and exposed for eight additional weeks to the weather, and the behavior of each piece was again studied.

Design of Experiment

The object of this experiment was to measure the effectiveness of 9 chemical compounds and 2 water repellent papers in alleviating or preventing bowing and crooking in southern yellow pine dimension. The chemical compounds tested were Dux Bax, Nelsonite 21P5 and Nelsonite 35P5, Woodfix 310, Woodtox 120, Wood Youth, Wood Lube, Wood Sealer No. 9521 (36 to 38 percent solids), and Wood Sealer No. 9521 (29 percent solids). The two paper wrappings tested were Shell-Flex 60-2P and Wrap-Dri-Type M Creped. Each compound and paper was tested in the original state as received from the cooperating firms. Thus there were 11 distinct treatments and the controls. Two control groups were employed at each exposure. By doubling the controls a fairly accurate standard was thus obtained for gaging the effectiveness of the various treatments.

The experiment was set up to provide 4 storage and exposure areas in the cities of Houston, Austin, Dallas, and Lubbock. Thirteen bins in each of the 4 retail yards were allotted for the storage. The 12 treatment groups were assigned to individual bins at random. This particular type of experiment is known as "randomized blocks". The 5,200 2 by 4's were randomly segregated into 13 treatment groups, numbering 400 per group. Each group consisted of 200 air-dried and 200 kiln-dried pieces. Upon completion of each group treatment, 4 subgroups consisting of 100 pieces per group were randomly chosen for distribution to the 4 storage locations. All subgroups were randomly distributed within the storage space and separately stacked in piles of equal dimension. At Houston and Austin all piles were on the same level in adjoining bins. At Dallas and Lubbock the piles were on three levels in adjoining bins.

Procedures

Before Treating: When the 5,200 pieces of lumber were delivered to the central sorting point they were immediately segregated into 13 groups as mentioned above. It should be mentioned that each of the 13 groups was allotted a proportionate number of pieces from each of the 7 sources from which the lumber was purchased.

As soon as the treatment groups were made up, each piece was given an identifying letter denoting the treatment, and a number. The kiln-dried pieces were numbered from 1 to 200; the air-dried pieces were numbered from 201 to 400. Letters and numbers were stamped with a hammer and steel die at each end.

Three moisture content readings were taken on each piece with a Model RF4 Moisture Register at intervals of 1, 4, and 7 feet from one end. These values were recorded, but the mean of the 3 readings was considered to be the moisture content of the piece.

Concurrent with the numbering and recording of moisture content, each piece was placed on a specially constructed table (Fig. 1) where the maximum deflection of bow (face curvature) and crook (edge curvature),[5] were measured to the nearest .05 inch.

Finally, each piece was inspected and placed in one of the 8 categories listed below. The first 6 of these categories were used in the Southern Pine Inspection Bureau survey. The last 2 were added shortly after the inspection began in order to provide a definite category for each piece. It should be noted that many pieces exhibited various combinations of several characteristics. Only the most obvious one was referenced to the piece in such cases.

Characteristics for Classifying Southern Yellow Pine 2-by-4 Lumber

1. Pieces showing 4 or more rings per inch on one end only.[6]

[5] Although many pieces were twisted only the maximum deflections in two planes were measured.

[6] Basis: paragraph 248, 1948 Southern Pine Inspection Bureau grading rules: "Medium grain lumber shall average on either one end or the other not less than 4 annual rings per inch, measured over a 3-inch portion of a radial line, if present, or over such portion less than 3 inches as may be present, and which shall be representative of the average growth on the cross-section.

2. Pieces showing less than 4 rings per inch on both ends but otherwise No. 1 quality. (See paragraph 256, 1948 Southern Pine Inspection Bureau grading rules.)

3. Pieces showing compression wood.

4. Pieces with pith on surface for all or part of the length.

5. Pieces showing 4 or more rings per inch on one or both ends and not showing the pith, but showing fast growth immediately adjacent to it.

6. Pieces showing abrupt rate of growth change on either or both ends. (Specify rate of growth in rings per inch for both fast and low growth).

7. Pieces showing less than 4 rings per inch on both ends.

8. Pieces not fitting any of the above categories that are No. 1 grade.

Table 1 summarizes the frequency distribution of the pieces of these characteristics for the 13 treatment groups.

Treating: All treatments were carried out at the Forest Products Department's headquarters, Lufkin, in accordance with written specifications and recommendations made by each cooperating firm for its product. In some cases the treating was done under the supervision of a qualified representative of the company supplying the chemical. An entire batch, or treatment group, of 400 pieces was completed, and the tank cleaned, before treating with another product.

The treating procedures described below for the various products were in accordance with each cooperating firm's recommendations.

1. *Nelsonite 21PS.* The product was used as shipped and the treating was done at the prevailing outdoor temperature. The studs were dipped for a period of 15 minutes, piled in normal fashion (bulk piled), and allowed to dry for 24 hours before further handling.

2. *Nelsonite 35P5.* The procedure was the same as for Nelsonite 21P5.

3. *Woodfix 310.* The product was used as shipped. Each piece was submerged for a minimum of 3 minutes. Stickers were placed between layers of the studs to insure treatment of all surfaces. After treatment, the studs were stacked with stickers and allowed to dry for a period of one week. The temperatures of both wood and solution were above 80° F.

4. *Woodtox 120.* The procedure was the same as for Woodfix 310.

5. *Wood Youth.* The product was shipped in a 2:1 concentrate to which was added twice the volume of petroleum mineral spirits (varsol) meeting the company's specifications. The concentrate was poured into the treating tank, into which the mineral spirits were added while stirring, until the solution was thoroughly mixed. The studs were dipped for a full 30 seconds with care being taken to insure submersion of all pieces. No stickers were required for treating. Immediately following treatment, the studs were allowed to drain until dripping stopped. The studs were then piled on stickers and allowed to dry for a minimum of 10 days.

6. *Wood Lube.* The procedure was the same as for Wood Youth.

7. *Wood Sealer No. 9521* (36 to 38 percent solids). The product was used as shipped. The studs were bulk dipped and were submerged for 15 minutes. After submersion, the studs were then placed on end in a dry place until they were dry enough to handle.

8. *Wood Sealer No. 9521* (20 percent solids). The product, as shipped, containing 36 to 38 percent solids was reduced to approximately 20 percent solids by the addition of 45 gallons of mineral spirits (varsol) to each 55 gallons of product. The treating procedure was the same as for Wood Sealer No. 9521 (36 to 38 percent solids).

9. *Dux Bax.* The product was used as shipped. No stickers were required during dipping, but the lumber was placed in the solution on edge and submerged for 3 minutes. Following treatment, the stock was placed in an inclined position and allowed to drip for from 3 to 5 minutes. The pieces were then piled on stickers and allowed to dry for 48 hours before handling.

10. *Paper Wrappings.* The studs were packaged in bundles of 10 to facilitate ease in handling. The ends were overlapped, folded in, and sealed with pieces of wide kraft tape. Three steel straps, with a piece of 9-point container board under each strap, were applied to each bundle to insure compactness.

Figure 1.—Table for measuring deflections of bow (face curvature) and crook (edge curvature) in 2 by 4 lumber, 8 feet long. Note the rigid metal surfaces forming a 90-degree angle fabricated by electrically spot welding angle iron to plate.

After Treating and Storage: When all treatments were completed, the treatment groups of 400 pieces were segregated randomly into four subgroups of 100 pieces. Thirteen subgroups, which included two subgroups controls, were distributed to the retail yards in Houston, Austin, Dallas, and Lubbock and stored in bins for 8 weeks. At the end of the storage period, each 2 by 4 was again inspected and maximum bow and crook were measured to the nearest .05 inch and recorded on the form with the initial deflections.

Moisture content readings were again obtained on each of the 800 control pieces. The average of 3 readings, taken at intervals of 1, 4, and 7 feet from one end, was computed, and again considered to be the moisture content of each piece.

Exposure to Weather: When the measurements were completed on each treatment group the lumber was then placed on the ground on the wide face,

Table 1.—SUMMARY OF GROWTH AND MANUFACTURING CHARACTERISTICS OF NO. 2 SOUTHERN YELLOW S.Y. PINE 2 BY 4'S BY TREATMENT GROUPS

Treatment Group	Characteristics								
	A[1]	B[2]	C[3]	D[4]	E[5]	F[6]	G[7]	H[8]	Total
Control	37	5	36	160	62	10	30	60	400
Control	29	4	41	111	72	5	69	69	400
Dux Bax	28	6	37	169	56	18	32	54	400
Wrap-dri	30	4	62	134	49	3	59	59	400
Shell-Flex	48	1	59	117	61	5	48	61	400
Nelsonite 21P5	29	5	69	122	54	5	58	58	400
Nelsonite 35 P5	43	8	44	134	51	5	76	39	400
Wood Sealer (37% Solids)	21	6	48	128	71	5	74	47	400
Wood Sealer (20% Solids)	15	3	64	173	65	9	34	37	400
Wood Youth	30	0	54	166	61	2	43	44	400
Wood Lube	25	0	50	175	60	5	34	51	400
Wood fix 310	21	2	48	188	60	3	34	44	400
Wood tox 120	23	0	37	176	57	4	40	63	400
Total	379	44	640	1953	779	79	631	686	5200
Percent of total	7.3	0.8	12.5	37.6	15.0	1.5	12.1	13.2	100.00

[1]Pieces showing 4 or more rings per inch on one end only.
[2]Pieces showing less than 4 rings per inch on both ends, but otherwise No. 1 quality.
[3]Pieces showing compression wood.
[4]Pieces showing the pith for all or part of its length.
[5]Pieces showing 4 or more rings per inch on one or both ends and not showing the pith, but showing fast growth immediately adjacent to it.
[6]Pieces showing abrupt rate of growth change on either or both ends.
[7]Pieces showing less than 4 rings per inch on both ends.
[8]Pieces not fitting any of the above categories that are No. 1 grade.

and left exposed to the weather for an additional 8 weeks. Storage in the bins during the hot summer months would test the effectiveness of the treatments in preventing loss of moisture; exposure in the open to the weather would test the effectiveness in repelling moisture.

After Exposure: During the interval between the end of the storage period and the end of the exposure period statistical analysis of data revealed those treatments which produced significant results. Therefore, measurements of bow and crook deflections after exposure were taken only on those treatment groups which showed significant results after storage. The deflections were again taken to the nearest .05 inch.

Analysis and Results

This investigation was conducted for the primary purpose of determining the relative effectiveness of several commercial chemical compounds and waterproof papers in alleviating or preventing bowing and/or crooking of southern yellow pine dimension.

It was realized from the start that little research has been done in the field of dimensional stabilization, particularly with sawn, one-piece, construction members. It was also realized that much of the critical bowing and crooking could be eliminated at the sawmill by the simple expedient of log selection and a change in sawing techniques. However, the project was designed to work with a representative sample of No. 2 grade, southern yellow pine 2-by-4 lumber and thus determine whether present commercial products could be of some benefit under present sawmill practices. This approach to the problem necessitated the use of a large sample at the sacrifice of some control due to the time involved between acquiring the lumber and recording preliminary data, and treating time. But this approach served the purpose of identifying some chemicals which, from a statistical analysis standpoint, produced significantly different results when compared to control groups.

The data were analyzed by 2 methods and for 2 sets of conditions. The first analysis consisted of purely statistical methods based on the well-known randomized block design. In this case the deflections of bow and crook, measured to the nearest .05 inch, and also the number of pieces in excess of the grading rule allowable ½-inch crook, were employed as the testing units. Analysis of covariance reduced the data for all treatments after storage and was again computed for those treatments involved in the exposure test.

The second analysis dealt with a determination of the effectiveness of the various treatments in controlling bowing and crooking among the 8 categories into which the lumber was segregated. Here again the number of pieces in excess of the grading rule allowable ½-inch crook were employed for comparative purposes.

Statistical Analysis: A straightforward analysis of covariance for a randomized-block design was employed. The tabulation following illustrates the elements in the analysis of covariance to learn the effects of the 9 chemical compounds and 2 wrapping papers on the behavior of southern yellow pine 2 by 4's.

ELEMENTS IN THE ANALYSIS OF COVARIANCE OF BEFORE AND AFTER TREATMENT DEFLECTIONS

Source of variation	Degrees of freedom
Total	51
Storage	3
Treatment	11
Error	37

Using the deflections measured before and after treatment, analysis of covariance was computed for both crook and bow.

After Storage: The statistical analyses showed highly significant differences due to storage location of the lumber and highly significant differences due to treatments.

Upon completing the tests of differences among the four storage locations of Houston, Austin, Dallas, and Lubbock, it was found that no differences existed between Houston and Austin nor between Dallas and Lubbock. However, a highly significant difference was shown to exist between the two cities of Houston and Austin combined and Dallas and Lubbock combined.

This evidence substantiates the complaints from West Texas retail lumbermen that crooking and bowing is more severe in West Texas than it is in East Texas. Shipments of properly dried dimension lumber leaving the East Texas area in good condition would after arrival and storage in summer in West Texas retail yards for a few days, reportedly contain up to one-third unsalable pieces.

The completed tests of significance for individual treatments showed only one chemical and both papers to be effective in controlling crook. Four chemicals and both papers were effective in controlling bow. Tables 2 and 3 summarize the degree of significance of the various treatments after the storage period in retail yards for a period of 8 weeks.

At this point it should be pointed out that although bow is defined under the Southern Pine Inspection Bureau standards as a characteristic or cause for grade limitation, actually, no limits are provided in the grading rules for rejecting severely bowed pieces of dimension. This is odd when considering that a 2-by-4, 8 feet long and severely bowed is just as useless at that length as is a severely crooked one. Moreover, it is just as likely to be rejected by the consumer. It is true that a moderately bowed stud still has utility when placed in wall construction, whereas a crooked stud cannot be used. Furthermore, if bowing occurs after a stud is in place, there is no immediate damage to the wall. This is not so when crooking occurs after the wall is constructed. In this case, stresses develop which are capable of buckling well-fitted panelling. With the lighter wall boards, or with lath and plaster, whole sheets of wall boards, and large sections of plaster are torn from the studs. The alleviation or prevention of crook therefore, is more to be desired than alleviating or preventing bow, although both conditions result from identical causes. It is largely a matter

Table 2.—RESULTS OF STATISTICAL ANALYSIS OF TREATMENT EFFECTS AFTER STORAGE (DEFLECTION METHOD)

Treatment	Behavior[1] Bow	Crook
Dux Bax	HS	HS
Wrap-dri	HS	HS
Shell Flex	HS	HS
Nelsonite 21P5	S	NS
Nelsonite 35P5	NS	—
Wood Sealer (37% Solids)	S	NS
Wood Sealer (20% Solids)	S	NS
Wood Youth	NS	NS
Wood Lube	NS	NS
Wood Fix 310	NS	NS
Wood tox 120	NS	NS

[1]Points of maximum deflection measured to nearest .05 inch.

HS Highly Significant—Only one chance in 100 for the means of treated and control groups to fall within estimated limits.

S Significant—One chance in 20 that the means of the treated and control groups would fall within estimated limits.

NS Not significant—No difference between means of treatment and control groups.

Note: In search for an independent means for substantiating the results from the analysis of measured deflections, consideration was given to a count of the pieces, expressed as a percent of the total pieces per treatment group that exceeded the maximum ½-inch allowable deflection specified in the grading rules. Analysis of covariance was employed and computed again for bow and crook. These results are tabulated in Table 3.

Table 3.—RESULTS OF STATISTICAL ANALYSIS OF TREATMENT EFFECTS AFTER STORAGE (PIECE TALLY METHOD)

Treatment	Behavior[1] Bow	Crook
Dux Bax	NS	S
Wrap-dri	HS	HS
Shell flex	HS	HS
Nelsonite 21P5	NS	NS
Nelsonite 35P5	NS	NS
Wood Sealer (37% Solids)	NS	NS
Wood Sealer (20% Solids)	NS	NS
Wood Youth	NS	NS
Wood Lube	NS	NS
Wood Fix 310	NS	NS
Wood tox 120	NS	NS

[1]Percent of pieces which exceeded the maximum ½-inch for 2 by 4 lumber allowed in grading rules based on total pieces per treatment group.

S—Significant.

HS—Highly significant.

NS—Not significant.

of how the piece is cut from the log that determines whether it will bow, crook, or twist. Kind, size, and location of knots, slope of grain, and exposed pith probably do more to cause twisting and cupping.

After Exposure: Analysis for after-exposure effect was made only on those 4 treatment groups showing significance after storage. Comparisons with the control groups were made both with measured deflections and with the percentages of pieces per treatment group in excess of ½ inch allowed for in the grading rules.

In this case, however, the effects of weather and treatment were the reverse of the effects of storage and treatment. In the latter case, the control groups (no treatment) and noneffective treatments exhibited the largest increases in bowing and crooking occurrence. The treatment, to be effective, would have to hold these increases to a minimum. In the former case, the rain thoroughly soaked the lumber. This soaking relieved internal stresses, causing many of the pieces to straighten out. The treatments which acted as good water repellents prevented thorough soaking, hence, the majority of the pieces which were bowed and crooked before exposure remained relatively so after exposure. Table 4 summarizes the results of this test by both methods, that is, by deflections and percentages of pieces in excess of the allowable ½ inch.

Table 4.—RESULTS OF STATISTICAL ANALYSIS OF TREATMENT EFFECTS AFTER EXPOSURE

	Method of Analysis			
	Deflection		Piece tally	
Treatment	Bow	Crook	Bow	Crook
Dux Bax	HS	S	HS	S
Nelsonite 21P5	S	NS	S	NS
Wood Sealer (37% Solids)	S	NS	S	NS
Wood Youth	HS	NS	S	NS

S—Significant.
HS—Highly significant.
NS—Not significant.

Notice again the similarity of results by the two methods. Here, as in the results after storage, only Dux Bax had a significant effect on alleviating crook and bow. Nelsonite 21P5, Wood Sealer (37 percent solids) and Wood Youth showed a significant effect only on bow after exposure. The two paper treated groups during the exposure period were used as control groups with the 2 original control groups and thus provided additional effectiveness to the results.

By Characteristics of Individual Pieces: An attempt was made to determine which, if any, of the groups that were classified according to growth and manufacturing characteristics responded to treatment. The 5,200 pieces were broken down into three categories for comparative purpose, namely: control, paper wrappings, and chemical treatment. A count of the increase in number of pieces, which contained deflections exceeding the ½ inch allowable under the grading rules, after treatment and storage was first determined. This was expressed as a percent of the number of pieces in that particular classification that did not exhibit bow or crook in excess of the allowable ½ inch before treatment and storage. Table 5 presents a summary of these results and indicates to a degree, at least, the type of 2-by-4 lumber that can or cannot be helped by chemical treatment.

Table 5.—COMPARISON OF TREATMENTS SHOWING EFFECTIVENESS IN CONTROLLING BOWED AND CROOKED 2-by-4 LUMBER WITH VARIOUS GROWTH AND MANUFACTURING CHARACTERISTICS

	Increase in number of pieces exceeding ½ inch after treatment			Increase expressed as a percent of classified pieces not exceeding ½ inch before treatment		
Characteristics	Controls	Chemicals	Papers	Controls	Chemicals	Papers
a	4	18	0	6.5	8.2	0.0
b	3	6	1	37.5	25.0	16.7
c	20	102	5	44.4	42.4	6.7
d	58	189	0	24.2	15.4	0.0
e	9	58	4	6.8	10.6	3.6
f	4	6	0	33.3	14.3	0.0
g	17	77	2	20.2	24.5	2.4
h	12	23	0	9.7	5.5	0.0

In table 5 it will be noticed that the paper wrappings were quite effective in alleviating and preventing bowing and crooking. It is, of course, realized that once the paper is removed drying will continue with subsequent bowing and crooking. One observation was made, however, which requires consideration. Moisture contents on the pieces in the same bundle had been pretty well equalized among all pieces and also throughout the length of each piece. Stresses were relieved or equalized. Points of maximum deflection shifted by as much as 3 feet on a single 2 by 4. In most cases this was accompanied by a reduced deflection. There is much that can be said in favor of the use of paper wrappings. Already one lumber company is wrapping its lumber because it is cheaper than building a dry shed.

Further study of table 5 indicates the types of lumber which did not respond generally to chemical treatment. Heading the list of these is characteristic "c", pieces containing compression wood. There was a 44.4 percent increase in the number of pieces exceeding the allowable ½ inch deflection in the controls and 42.4 percent increase in the chemical treatment group. Twelve and one-half percent of the 5,200 pieces were classified as containing compression wood. The next categories which obviously were not helped by chemical treatment were "a", "e" and "g". Category "a" contains pieces showing 4 or more rings per inch on one end only and comprised 7 percent of all the pieces. Category "e" contains pieces showing 4 or more rings per inch on one or both ends and not showing the pith, but showing fast growth immediately adjacent to it. Category "g" contains pieces showing less than 4 rings per inch on both ends. The latter two categories made up 27 percent of the total. An examination of category "d" which comprised 37 percent of the 5,200 pieces reveals interesting results. These pieces exhibited pith on a surface for all or part of the length. The number of bowed and crooked pieces was reduced by about 36 percent by treatment, all of which occurred in the bowed pieces. Only 0.2 percent reduction occurred in the crooked pieces after treatment.

Summarizing, category "a", pieces showing 4 or more rings per inch on one end only, categories "c", pieces containing compression wood, and "g", pieces showing less than 4 rings per inch on both ends, which made up approximately 32 percent of the total were not helped by chemical treatment. All of these categories are based on growth characteristics — compression wood and less than 4 rings per inch— and could be eliminated by log selection. Categories "d", pieces with pith exposed for all or part of a surface, and "e", pith not exposed but showing fast growth adjacent to pith on one side of the piece, comprised about 53 percent of the total pieces. Category "d" is based on manufacturing practice while "e" is a combination of growth and manufacturing practice. Hence by a combination of selecting logs and altering sawing practices approximately 85 percent of the types of dimension causing the most serious bowing and crooking could be eliminated. Bowing was reduced in about 10 percent of the number of pieces in category "d".

Conclusions and Recommendations

The following conclusions and recommendations can be made from this portion of the study:

1. Based on statistical analysis two commercial chemical compounds, Dux Bax and Nelsonite 21P5 and two commercial wrapping papers, Wrap-dri and Shell-flex have proven their ability to alleviate bowing and cooking in No.

2 southern yellow pine 2 by 4's lumber 8 feet long having certain charactertics.

2. Based on an analysis of the number of pieces exceeding the ½ inch deflection allowed for by the grading rules for 8 categories, approximately 25 percent of the total pieces were helped by chemical treatment.

3. Paper wrappings practically prevented bowing and crooking from occurring, and in most categories, pieces that exceeded ½ inch of bow or crook, before wrapping did not exceed ½ inch after wrapping and storage.

4. Pieces fitting category "a", showing 4 or more rings per inch on one end only, categories "c", containing compression wood, and "g", showing less than 4 rings per inch on both ends, both of which are growth characteristics, comprised 32 percent of the total sample and were not helped by chemical treatment. Pieces fitting categories "d", pith exposed for all or part of a surface, and "e", pith not exposed but showing fast growth adjacent to pith on one side of the piece, both of which are largely manufacturing practices, comprised 53 percent of the total sample. Forty-three percent of the total pieces in these two categories were not helped by chemical treatment.

5. Bowing and crooking is more severe in the Dallas–Lubbock area than in the Houston–Austin area.

6. Because of the large number of pieces involved in the study which made close control difficult at the initiation of the project, further investigation with the 2 chemical compounds with proven ability to alleviate bowing and crooking is warranted.

7. Efforts by the manufacturers of southern yellow pine to practice log selection and to alter their sawing practices are justified so far as economically feasible. By adopting such measures as log selection, new sawing techniques, and chemical treatment, three-fourths of the bowing and crooking exceeding the ½-inch limits allowed by the grading rules can be eliminated.

High-Temperature Drying: Its Application to the Drying of Lumber

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The history of superheated-steam kilns and other high-temperature kilns both in the United States and abroad is briefly outlined. The construction and operation of the newer types are described. Foreign investigators report a marked reduction in drying time and heat energy required for drying pincipally air-dried softwoods, although the drying of green softwoods and air-dried hardwoods has been carried on to some extent also. Generally, the newer types of kilns have a capacity of only 2,000 or 3,000 feet, board measure, and in Germany are being used primarily in small industries. The effects of high-temperature drying on casehardening, discoloration, hygroscopicity, and certain strength properties are discussed briefly.

DURING WORLD WAR I, superheated-steam kilns were used in the Pacific Northwest and very rapid drying rates were reported. Some green 1-inch softwoods were dried to 10 percent moisture content in 24 hours, at drying temperatures as high as 230° F. in an atmosphere of steam. The relative humidity of the steam was regulated by controlling the dry-bulb temperature and maintaining a wet-bulb temperature at the boiling temperature of water (212° F.). The method is applicable to 1-inch Douglas-fir, true firs, western hemlock, ponderosa pine, southern yellow pine, basswood, and sapwood of sweetgum. So far as is known, it is not suitable for other hardwoods or for softwoods that have a tendency to collapse. While the reduction in drying time was well worthwhile, the severe drying conditions caused such rapid deterioration of materials used in kiln construction that the use of superheated-steam kilns was discontinued in the United States.

While there has been a recent revival of interest in the use of superheated-steam kilns, the principle of drying lumber by this method was recognized as early as 1867 when U. S. Patent No. 64,398, "Apparatus for Drying and Seasoning Lumber by Superheated Steam," was granted to C. F. Allen and Luther W. Campbell, Aurora, Ill.,U. S. Patent No. 1,268,180 was granted to H. D. Tiemann, Madison, Wis., June 4, 1918, for a superheated-steam dry kiln in which circulation was induced by four pairs of steam-spray lines arranged in such a manner that the direction of circulation could be reversed.

Within the past several years considerable publicity has been given to three German high-temperature kilns. Early forms were constructed of steel or of masonry. In figure 1 is a transverse section of a kiln with an aluminum lining, insulated with about 5 inches of glass wool covered with a steel shell (2).[2] Such construction is welded so as to be vapor tight and is intended to reduce heat loss and deterioration of the metal. The modern kiln can be completely assembled at the factory and shipped as a unit ready for use as soon as steam and electrical connections are made. For foreign shipments, partial disassembly for crating is advantageous. It has been reported that 100 of these kilns have been installed in West Germany, two in Sweden, three in Canada, and several in South America. None are known in the United States. Since ordinarily they have a capacity of 2,000 to 3,000 feet of lumber, board measure, they are used primarily in small industrial plants (7).

Circulation in German high-temperature kilns is stimulated by disk fans or by centrifugal fans. The disk type is suitable when the resistance to flow is low, and the centrifugal type when the resistance is high. The disk fans are reversible. The fan axes may be parallel to or horizontally or vertically perpendicular to the long axis

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Numbers in parentheses refer to Literature Cited at end of this report.

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of the kiln (10). The motors are mounted outside the kiln.

Customarily, air-dried softwoods are loaded into a kiln in the morning, the vents and fresh-air intakes are closed, the steam-spray valve is opened unless the evaporated moisture is sufficient to maintain the desired relative humidity, the fans are started, and the heat, either steam or electric, is turned on for several hours, during which the temperature rises to 230° or 239° F. The temperature is maintained for 4 to 10 hours, and then the heat is shut off automatically (7). In some cases, the vents and fresh-air intakes are partially opened as soon as the maximum temperature is reached; but ordinarily they are not fully opened until the heat supply is shut off. The wet-bulb temperature may be maintained at 212° F., but generally is somewhat lower. The fans are in operation during the entire kiln run, which is about 24 hours. Ordinarily, these kilns are not equipped with wet- and dry-bulb recorder-controllers. In some cases, however, the dry-bulb temperature is thermostatically controlled (7).

Basically, water vapor is superheated when, at any pressure, its temperature exceeds that of the saturated vapor. When the wet-bulb temperature is below 212° F. at atmospheric pressure, both air and water vapor are present. When the wet-bulb temperature reaches 212° F., no air is present. Further heating of the vapor results in superheated steam at atmospheric pressure. In other words, if the wet-bulb temperature in a kiln is below 212° F., the kiln may be called a superheated-vapor kiln. On the other hand, if the wet-bulb temperature is 212° F., and if the dry-bulb temperature is above 212° F., the kiln may be called a superheated-steam kiln. If, however, the dry-bulb temperature is above 212° F., the term "high-temperature" may be applied to the kiln irrespective of whether the wet-bulb temperature is at or below 212° F.

In order to release heat for evaporation in a kiln at temperatures below the boiling point of water, the temperature of the air and vapor is lowered. The air, of course, can give up heat for evaporation as long as its temperature is higher than that of the wood to be dried. The vapor, on the other hand, can, as its temperature drops, supply heat for evaporation only until the point of saturation is reached. At the standard atmospheric pressure of 14.696 pounds per square inch absolute, or zero pound gage, the temperature of saturated steam is 212° F. Wood in contact with such steam could be heated, but the water in it could not be evaporated.

Relative humidity may be defined as the ratio of the actual vapor pressure to the pressure at saturation at the given temperature. For example, at a dry-bulb temperature of 150° F. and a wet-bulb temperature of 132° F., psychrometric curves (such as those in fig. 2) commonly available to dry-kiln operators show that the dew point is 130° F. and the relative humidity is about 60 percent. In steam tables, which are commonly given in handbooks and textbooks on mechanical engineering, physics, or chemistry, the saturated-vapor pressure at 130° F. is 2.222 pounds per square inch absolute. The corresponding saturated-vapor pressure at 150° F. is 3.718 pounds per square inch absolute. The relative humidity is then 2.222/3.718 = 59.8 percent, which checks with the percentage determined from the curves as described above. When, however, a German high-temperature dry kiln is operating with a dry-bulb temperature at 230° F. and a wet-bulb temperature of 194° F., the relative humidity is less and cannot be readily calculated from steam tables. Since 230° F. and 194° F. are respectively 110° C. and 90° C., however, the corresponding relative humidity may be determined from the curves shown in figure 3, which was prepared by R. Keylwerth (8). Intersection of a horizontal line through 110° C. with the 90° C. wet-bulb temperature line (sloping upward from left to right) corresponds to a relative humidity of about 49 percent as shown on the horizontal axis.

Suppose now, that saturated steam at 14.696 pounds per square inch absolute is superheated from 212° F. to 230° F., while the atmospheric pressure remains unchanged. In other words, the steam is superheated 18° F. Referring again to steam tables, we find that at 212° F. the vapor pressure is 14.696 pounds per square inch absolute, and at 230° F. the vapor pressure is 20.780 pounds per square inch absolute. The relative humidity is then 14.696/20.780 = 70.7 percent.

Most kiln operators are familiar with the relationship of temperature and relative humidity to equilibrium moisture content for temperatures below the boiling point of water at atmospheric pressure. A number of investigators, notably in Germany (8) and in Australia (4), have performed experiments to determine the equilibrium moisture content of wood exposed at atmospheric pressure to superheated steam at temperatures up to 300° F. Eisenmann (2) determined corresponding values for pressures up to 3½ atmospheres, or about 51 pounds per square inch absolute, as shown in figure 4. In this figure, the heavy horizontal and vertical lines show four combinations of temperature and relative humidity, all of which correspond to an equilibrium moisture content of

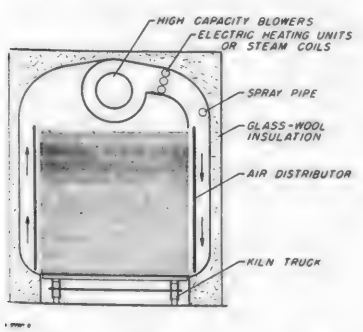

Figure 1.—High-temperature kiln constructed of aluminum and sheet steel separated by heat-insulating material.

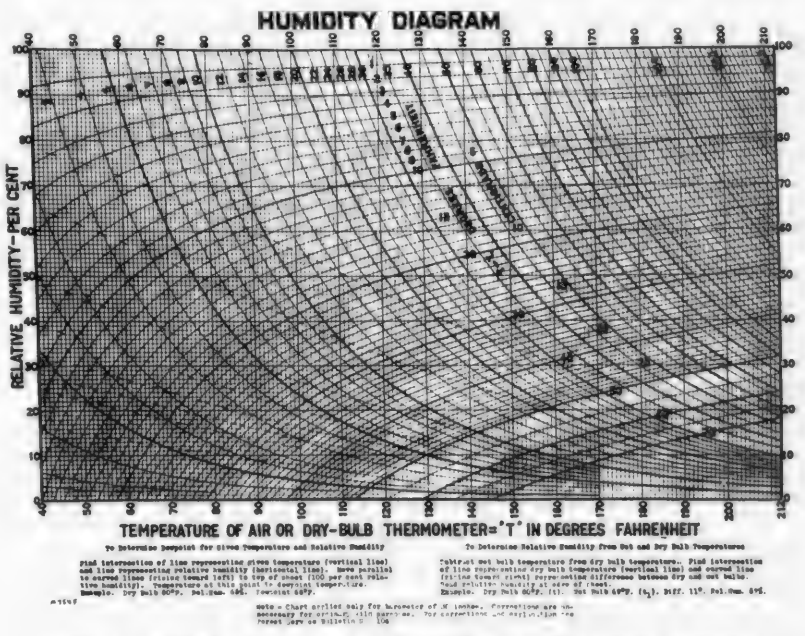

Figure 2.—Humidity diagram. (By H. D. Tiemann, U. S. Forest Products Laboratory.)

8 percent. It is interesting to note that at least up to 248° F. the determinations at atmospheric pressure (fig. 3) correspond well with estimates arrived at by the mathematical extrapolation (9) of curves (fig. 5) prepared at the U. S. Forest Products Laboratory and dated May 21, 1926.

Kiln Temperatures

Kollman (8) states that drying by superheated steam is suitable for softwoods and beech, but not for green hardwoods, such as oak, which checks and collapses readily. If they are air dried, or kiln dried at a moderate temperature to 25 percent, they can be further kiln dried at a high temperature without checking. In superheated steam at 120° C., the equilibrium moisture content of wood is 4.5 percent, and at 130° C. it is only 3 percent. Kollman regards these conditions as too severe and recommends a maximum temperature of 115° C. In this case, the equilibrium moisture content is about 5.5 percent. He, as well as Egner (1), considers a range of 110° to 115° C. as being most expedient. At 100° C. the equilibrium moisture content is 7 percent.

In figure 6[3] is shown an example of conditions in a superheated-vapor kiln during the drying of 1-inch spruce from a moisture content of 30 to 8 percent in 6 hours. The initial temperature of the wood was 68° F. During the first 1½ hours the relative humidity rose to 85 percent. The wet-bulb temperature during most of the next 4-hour period was slightly below 100° C. (212° F.) As the dry-bulb temperature rose to 118° C. (244° F.), the relative humidity dropped to 52 percent and then fluctuated between 48 and 53 percent while the dry-bulb temperature remained constant at 118° C. Practically all the drying occurred during 4½ hours.

Drying Gradient

Keylwerth (6) developed a concept that the ratio of the moisture content (below the fiber-saturation point) of the lumber at a given instant to the equilibrium moisture content should be a constant. He set up the condition that the equilibrium moisture content should be chosen so that the lumber during the entire drying process would always require the same time to reach that equilibrium. Mathematically, he expressed the concept thus:

$$\frac{u_m}{u_{g1}} = \text{constant}$$

where u_m is the instantaneous moisture content and u_{g1} the corresponding equilibrium moisture content. To this ratio he applied the term "drying gradient" and worked out the following values, which are applicable below the fiber-saturation point.

1. For mild drying conditions and high-quality stock, or for stock thicker than 1.2 inches: hardwood, about 1.5; and softwood, about 2.0.

2. For more severe drying conditions and low-quality stock, or for stock less than 1.2 inches in thickness: hardwoodwood, 2.0 to 3.0; softwood, 3.0 to 4.0.

Above the fiber-saturation point the equilibrium moisture content is maintained constant at 14 to 18 percent, depending on the particular item being dried.

Rates of Circulation

Various investigators advocate rates of circulation of 2 to 10 meters per second (394 to 1,970 feet per minute); 2 to 3 meters per second (394 to 590 feet per minute) are most commonly mentioned. Among the factors affecting the rates are, presumably, differences in species, in initial moisture content, in temperature, in relative humidity, and in length of air travel. Sturany (11) refers to "amount of air exchanged," rather than to linear rate. He states that in a certain superheated-steam kiln, the amount of "air" is exchanged 2,100 times, while for standard kilns the corresponding figures range from 200 to 800. The usual rates of circulation in American ventilated kilns range from 250 to 350 feet per minute. Because high temperatures result in high rates of drying, it is to be expected that the rates of circulation mentioned for foreign kilns would be higher than those in American kilns in order to carry the moisture away from the lumber as rapidly as it comes to the surface.

Energy Required for Drying

Keylwerth (5) indicates that, with a superheated-vapor kiln, the usual range of energy required is 1.2 to 1.5 kilowatt-hours per kilogram (2.2 pounds) of water evaporated, and that the corresponding range is 2 to 4 kilowatt-hours with low-temperature drying. He attributes the lower energy requirement to the lower heat loss, lower heat capacity of the construction materials, and the shorter drying time in the case of the superheated-vapor kiln.

Eisenmann (3) cites an example of the drying of 1-inch spruce from a moisture content of 30 to 6 percent after it was heated for 4.5 hours in a superheated-vapor kiln. In this connection the following data were tabulated for an electrically heated kiln:

Ovendry weight of wood: 350 kilograms per cubic meter (21.9 pounds per cubic foot)
Reduction of 24 percent in moisture content: 84 kilograms (185 pounds)
Heat requirtd to evaporate 1 kilogram of water at 20° C.: 620 kilocalories 2,460 British thermal units)
84 kilograms of water require: 52,080 kilocalories (207,000 British thermal units)
1 kilowatt-hour is equivalent to: 860 kilocalories (3,415 British thermal units)
74 kilowatt-hours[4] required per cubic meter of wood is equivalent to: 63,640 kilocalories 252,650 British thermal units)
Loss:
63,640 — 52,080 = 11,560 kilocalories
11,560 ÷ 63,640 = 18 percent

In American practice, if softwoods are kiln dried, they are loaded in the green condition and ordinarily require 2 to 2.75 pounds of steam per pound of water evaporated. If, for example, the figure 2.5 is chosen, the percentage heat loss due to all causes is

$$\frac{2.5 - 1.0}{2.5} = 60 \text{ percent.}$$

Distribution of Moisture

Some investigators have indicated considerable difficulty in attaining a reasonable degree of uniformity in moisture content values among kiln-dried boards. Eisenmann (2), however, reports the following when a stack of 1-inch spruce about 2.6 feet wide, 4.6 feet high, and 13.1 feet long was dried from a moisture content of 35 percent to 8.5 percent in 4 hours 50 minutes in a superheated-vapor kiln. Twenty-seven average moisture content values were determined: at both ends and at the middle of each of 9 boards in the top, middle, and bottom layers of the stack. Three of the boards tested were in each of the two outer tiers and three in the middle tier. One value, 14.5 percent, was the highest, and Eisenmann believed that it was in error. With this exception, the range of the 26 other values was 6.5 to 10.4 percent, with an average of 8.5 percent.

Transverse moisture-distribution determinations were made by Eisenmann on one board that was ripped into six strips, and three of these strips were resawed into three pieces of equal thickness. The moisture content values of the outer zones ranged, he reported, from 8.5 to 10.2 percent.

By American standards, the ranges in average moisture content and in transverse moisture content distribution in this case are satisfactory. It is to be recalled, however, that the distance across the load was only 2.6 feet. The permissible drop in temperature across the load is usually stated as 5° C. (9° F.); if the circulation is reversed periodically, the corresponding drop is 2½° C. (4½° F.). Whether these temperature differentials apply to green or only to air-dried stock is not clear.

[3] Brochure No. 1360 issued by Maschinenfabrik G.g. Kiefer, Stuttgart-Feuerbach, Germany.

[4] Whether this value includes energy for fan motors is not indicated.

Effects of High-Temperature Drying on Wood Properties

Kelywerth (5) found that samples of red beech dried in superheated steam at 115° C. (239° F.), as compared with those dried at 65° C. (149° F.), had an equilibrium moisture content value about 2 percent lower at 12 percent moisture content; also, they had somewhat higher modulus of rupture, maximum crushing strength, and modulus of elasticity. In impact bending and in tension perpendicular to the grain, however, the samples dried at 115° C. had somewhat lower values. The radial and tangential shrinkages were reduced 24 and 20 percent, respectively. Graf and Egner (2) reported that pine dried at 115° C. shrank and swelled only 70 percent as much as air-dry pine.

Available information concerning the effect of high-temperature drying on case-hardening is not very detailed. General reports indicate, however, that case-hardening resulting from this method of drying is not of commercial importance in Germany.

Kollman (8) determined "relative whiteness" of pine boards photospectrographically over a considerable range of wave lengths, after drying them in a steam-air mixture at temperatures of 60° to 140° C. (140° to 284° F.). His conclusions were as follows:

1. The action of temperature during the first 5 to 10 hours has the greatest influence on whiteness.

2. The discoloration is slight up to 70° C. (158° F.), moderate between 70° C. and 140° C., and heavy above 140° C. (284° F.).

3. In the moisture content range of 0 to 15 percent, the effect of moisture content is negligible; between 15 and 40 percent, the effect is perceptible; and above 40 percent the effect is marked.

Data obtained by the Forest Products Laboratory have indicated, for example, that in ordinary kiln drying of 6/4 ponderosa pine sapwood it was possible to minimize brown stain by applying a low-temperature, low-humidity schedule: for example, one with initial conditions of 120° F. and 55 percent relative humidity and with final conditions of 160° F. and 24 percent. The commonly accepted theory is that chemical brown stain usually results from chemical reactions that occur in water-soluble extractives as they are concentrated and deposited during drying. It is quite possible that, at the very high temperatures cited by Kollman, the movement of moisture in the vapor phase, rather than in the liquid phase, predominated. If this be the case, it would be expected that the concentration of extractives and consequently the discoloration would be less. Furthermore, the much shorter drying time at high temperatures may be an important factor. There is also some evidence that the discoloration that does occur at high temperatures can be readily surfaced off, whereas in ordinary kiln operation the entire cross section of a board may be heavily discolored.

Conclusions

In recent years marked advances have been made in the construction of high-temperature kilns in Germany. The kilns are well insulated and vapor-tight, so that heat losses and deterioration of the construction materials are minimized. Moreover, the operating temperatures of up to 115° C. (239° F.) permit very rapid drying of lumber. In some instances drying time has been reduced 80 percent. While most of the kilns of this type can be operated with a wet-bulb temperature at or below 212° F., they are ordinarily operated at a wet-bulb temperature below 212° F. One advantage of such operation is a reduction or elimination of chemical discoloration.

Another advantage, as compared with that resulting from drying in a standard ventilated kiln, is a reduction in hygroscopicity. Increases in some strength properties and losses in others are reported. By and large, however, German investigators do not consider the changes in strength properties important.

It would be desirable to begin an investigation of the effects of high-temperature drying on hardwoods and softwoods growing in the United States.

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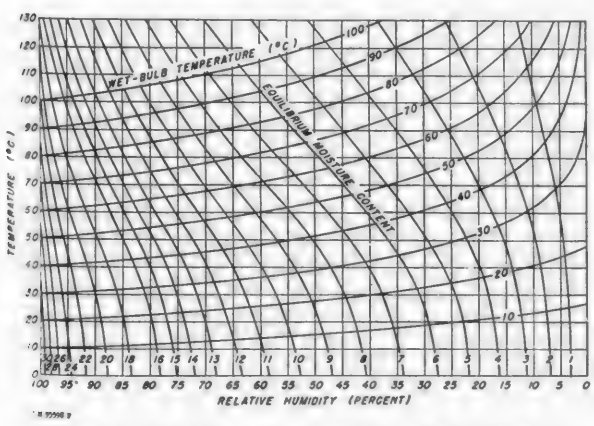

Figure 3.—Chart of hygroscopic equilibrium for softwoods. (By R. Keylwerth.)

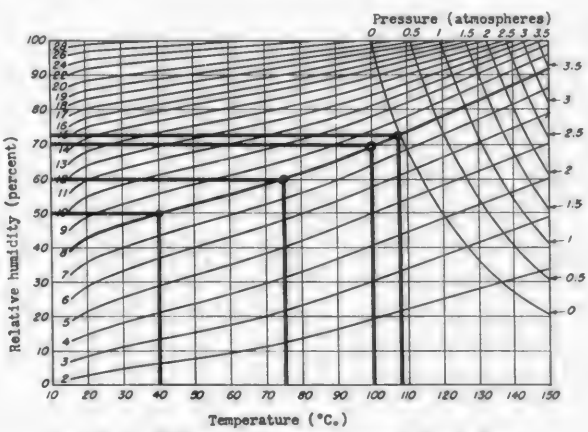

Figure 4.—Equilibrium moisture content curves. Values above 100° C. by E. Eisenmann.

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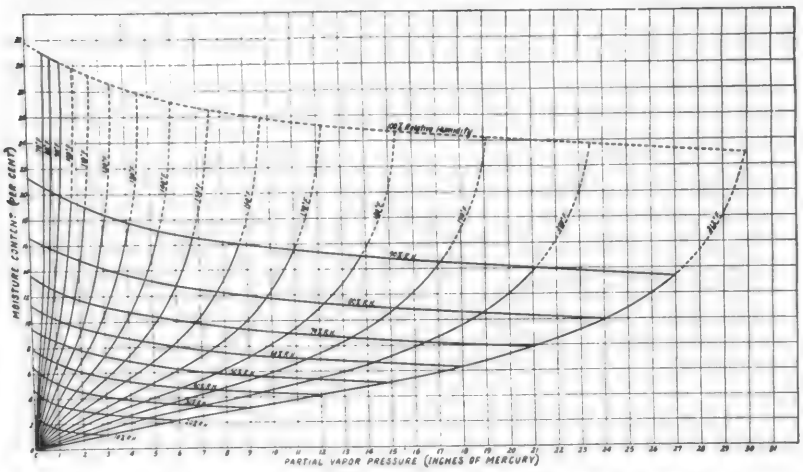

Figure 5.—The moisture content of Sitka spruce at equilibrium with the indicated temperature, partial vapor pressure, and relative humidity. (By W. K. Loughborough, U. S. Forest Products Laboratory.)

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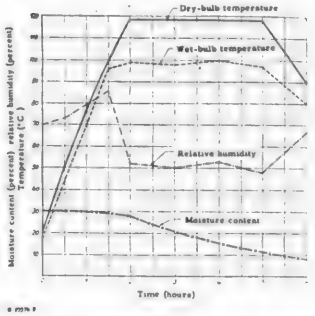

Figure 6.—Conditions in a high-temperature kiln during the drying of 1-inch spruce from a moisture content of 30 to 8 percent in 6 hours. The initial temperature of the wood was 20° C. (68° F.).

The Effect of Rays on the Differential Shrinkage of Red Oak [1]

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THE SHRINKING and swelling of wood, which accompany changes in moisture content occurring in response to variations in the relative humidity of the atmosphere, present serious problems to those who manufacture or use wood products. This dimensional change is different in the longitudinal, tangential, and radial directions, longitudinal shrinkage is normally very small and is usually not considered important. The transverse shrinkage values, however, are of a much greater magnitude; the tangential values range from 4 to 14 percent of the green dimension whereas the radial values are approximately one half of this amount. It is these shrinkage percentages, or the differences between them, that give rise to cupping and checking of lumber and logs, the warping of veneered constructions and many other serious problems familiar to those who are associated with wood products.

Numerous theories have been advanced to explain the differences in transverse dimensional change accompanying a change in moisture content, no one of which has been universally accepted. The oldest theory, which may be called the "Ray Restraint" theory, assumed that rays shrank very little along their axes and since they were aligned radially, or perpendicular to the longitudinal elements, they restrained the radial shrinkage of the wood. Barkas (1), Clarke (2), Greenhill (4), and Koehler (5), have expressed their belief in this theory. Kollman (6) rejected the explanation on the basis that the strength of the ray cells was not sufficient to enable them to restrain the radial shrinkage of the wood.

Ritter (8), from evidence obtained in microscopical studies with polarized light, stated that the crystalline portions of ray cells are arranged vertically and thus parallel to the crystalline portions of the longitudinal cells in the wood. The ray cells would then logically be expected to shrink and swell the same amount as fiber cells in a radial direction. In a further attempt to demonstrate the lack of ray restraint on radial shrinkage, Ritter and Mitchell. (9) measured the shrinkage of pine blocks from which the rays had been removed by degradative action. They concluded that the shrinkage of the blocks with the rays removed was comparable to that of the blocks with the rays present, which supported the belief that rays have no restraining action on radial shrinkage. These researchers have, upon further investigation, advanced a theory relating differential transverse shrinkage to deviations in the fibril angles of the radial and tangential cell walls of the longitudinal cells of the wood. It is claimed that pits increase the fibrillar deviation in radial walls, thereby reducing the radial shrinkage. Pentoney (7) stated that although this may be a mechanism involved in the differential shrinkage, it cannot, in itself, explain the phenomenon.

Morath (8) hypothesized that the discrepancy in transverse shrinkage values was due to the alternating bands on wood components of different densities (springwood and summerwood) found in woods of the temperate zones. Pentoney (8) examined this theory experimentally, measuring the shrinkage values of springwood and summerwood of Douglas fir, and concluded that it largely explained the differential shrinkage of this wood. Ritter and Mitchell (9), however, also empirically examined the theory, using longleaf pine specimens. Their conclusion was that the summerwood–springwood interac-

[1] Winning paper in Graduate Division, 1954 Wood and Wood Products Award, presented by Vance Publishing Co., Chicago. Condensed from thesis toward MS degree.

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tion is only a minor contributing factor in differential transverse shrinkage.

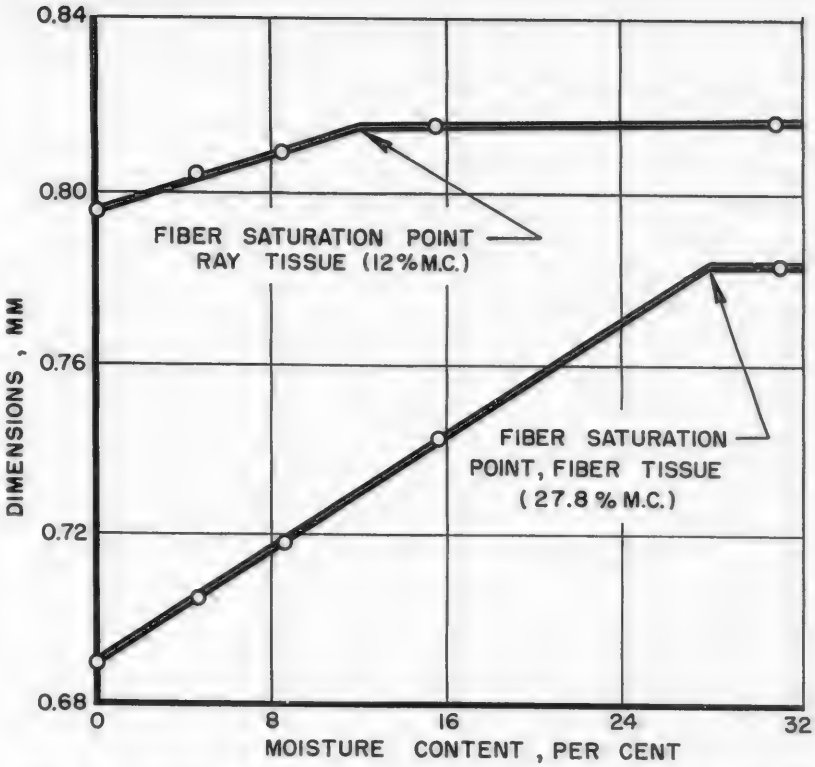
Another theory, advanced by Frey-Wyssling (3) relates differential shrinkage to the shrinkage properties of the compound middle lamella. There is no record in the literature of this theory being tested by other investigators.

With the hope that additional data might clarify the role of ray tissue in differential shrinkage, this experiment was undertaken to determine (1) the magnitude of difference between shrinkage values of ray and adjacent tissue, (2) what factors other than differences in orientation of crystalline areas of the cell wall might contribute to differences in shrinkage values of ray and adjacent tissue, and (3) whether isolated fiber tissue shrinks differently in the tangential and radial directions. Data were collected to permit examination of the following possible causes for any differences that might exist between radial shrinkage of fiber and ray tissue: (1) differences in density of tissue type, and (2) differences in fiber saturation point of tissue type.

Experimental Design and Procedure

Red Oak (*Quercus borealis* Michx. F.) was chosen for the experimental work because it contains broad rays which are large enough to provide specimens of a size easily handled and measured. Four small trees (8–10 inches in diameter) were felled and a three-foot bolt was taken from the butt section of each. Four cross-sectional discs approximately one-inch along the grain were removed from each bolt. Two small radially adjacent blocks, suitable for sectioning on a microtome, were removed from each of the sixteen discs from portions having approximately the same rate of growth. These blocks were stored in water until the time of sectioning. The unused portions of the discs were stored in damp sawdust so they might be used later to determine the shrinkage values of the wood. One block of each radial pair was used to determine the specific gravity; the other provided material for the tissue-shrinkage study.

Radially cut sections of broad ray tissue and radially and tangentially cut sections of fiber tissue, approximately 30 microns thick, were prepared from each block with a microtome. After sectioning, tissue specimens of a size conveniently measurable were dissected using a scalpel on a glass slide. The tangentially cut specimens of fiber tissue had the broad rays removed but contained some small rays. In addition to the tissue-shrinkage specimens, tangential and transverse sections approximately 15 microns thick were cut from several of the blocks for the determination of the density of ray and fiber tissue.



The tissue-shrinkage specimens were placed on a glass slide, covered with a cover slip, and measured to a precision of 1 micron at 125 diameters magnifcation using a microscope equipped with a mechanical stage and a calibrated filar micrometer ocular. Each specimen was measured successively in the saturated state and at 15, 8, 5, and 0 percent moisture content. Moisture content, intermediate between saturated and oven-dry, was controlled by conditioning the specimens, with the cover glass removed, to equilibrium, and measuring them, in humidity rooms regulated to the equilibrium conditions of each moisture content level. Oven-dry specimens were conditioned in an oven controlled to 212 degrees F and were measured immediately upon removal while the glass slide and section were still hot. From these measuremnts, percentage shrinkage from green to oven-dry, based on green dimension, was computed in the conventional manner for each specimen of radially cut ray and fiber tissue and tangentially cut fiber tissue.

The fiber saturation point for each type of specimen was determined by the shrinkage method which is based on the fact that shrinkage does not accompany moisture content reduction above the fiber saturation point but is essentially rectilinearly related to moisture loss below the fiber saturation point. Therefore, if a graph is plotted with the moisture content as the axis of the abscissa and the dimensions of the specimen as the axis of the ordinate, the plot will be a straight line paralled to the axis of the abscissa from the initial saturated moisture content to the fiber saturation point where it will intersect with the sloping line expressing dimension as a function of moisture content below the fiber saturation point. Thus, the moisture content at fiber saturation point may be graphically determined for a specimen for which dimensions at various moisture content percentages between the saturated and oven-dry conditions are known. The shrinkage-moisture content relationship is not truly rectilinear but, with little error, may be considered so for this purpose. Figure 1 shows curves typical of the type used for the determinations of fiber saturation points. In all, shrinkage from green to oven-dry, and moisture content at fiber saturation point, were determined for 16 radially cut ray specimens and 16 each radially and tangentially cut fiber specimens, making a total of 48 specimens.

The section for tissue-density determination were photomicrographed in the green condition and the pictures were enlarged to 1300 diameters. For each of 28 randomly selected ray and fiber cells measurements were taken of areas occupied by the cell walls and lumina on the section perpendicular to the long axis of the cells in the tissue type. Thus, transverse and tangential sections were used respectively for fiber and ray studies. A planimeter was used to determine the areas of the cells and

of their lumina in the pictures. Since the thickness of all specimes photographed was the same, a relative density factor based on cell-wall area per unit area of tissue could be computed. The relative density factor of the tissue was computed by the equation,

$$RDF = 1.5 \frac{(OA-LA)}{(OA)}$$

in which RDF = relative density factor (swollen cell wall material is assigned a value of 1.5 to yield a factor approximating specific gravity.)

OA = overall area occupied by cell

LA = area occupied by lumen

The factor computed by the above equation does not consider the end walls of the cells in either tissue type and consequently yields a value which is slightly low, particularly for the ray tissue.

The radial and tangential shrinkage of the wood was determined by measuring radial and tangential shrinkage blocks two inches long cut from the remaining portions of the green discs which were stored in damp sawdust, The moisture content at fiber saturation point for each of the thirty-two blocks was also determined.

Results and Discussion

The results of the shrinkage measurements of specimens of the radially cut broad ray tissue and of both the radially and tangentially cut fiber tissue are found in Table 1.

It is evident that ray tissue shrinks only a fraction as much in the radial direction as does the adjacent fiber tissue. Although variation within a tissue type was appreciable, in no case did the shrinkage of ray tissue approach that of fiber tissue in magnitude, and differences were found to be statistically very significant by the use of the *t* test. The striking difference in shrinkage percentages of ray and fiber tissue clearly suggests that the rays may exert an important influence on differential shrinkage.

The average tangential shrinkage of fiber tissue was 14.01 percent, which was not statistically greater than the value for radial shrinkage (11.97 percent) at the five percent level. These figures suggest that, for fiber tissue at least, differential fibril alignment in radial and tangential walls is probably not an important factor in differential transverse shrinkage.

Differences in shrinkage of fiber and ray tissue may be partially explained by differences in fiber saturation point, the values for which appear in Table 2.

The average value for fiber tissue determined from radial shrinkage is considerably higher than that for ray tissue. As in the case of shrinkage percentage, this difference was found to be statistically very significant by the use of the *t* test. Average fiber saturation point values for fiber tissue determined form radial and tangential shrinkage values were respectively 25.57 and 30.15 percent moisture content (from Table 2) and, like shrinkage values, were not statistically significant at the five percent level.

Another possible cause for differences in ray and fiber shrinkage was found to be density differences between the two types of tissue. The average relative density factor for fiber tissue was 1.14, whereas that for the ray tissue was but 0.76. Microscopic observations of swelling ray cells indicated that the lumina did not change measurably in dimension and hence, like fiber tissue, shrinkage of ray tissue may be expected to be proportional to specific gravity (10).

It should be noted that density differences may not be so great as the density factor would indicate, because the end walls of the cells which are not considered would have a more pronounced effect on ray tissue, tending in all probability to decrease the difference in density of the two tissue types. However, the apparent difference in density of the two types of tissue suggests that correlation between gross or total ray volume and differential shrinkage may be misleading if the density difference between rays and surrounding wood is not also considered.

The shrinkage of the wood, determined by the shrinkage of the 2-inch blocks, was 5.14 percent radially and 8.53 percent tangentially. These two average figures fell between the shrinkages of the two tissue types. The tangential shrinkage value may be low because the shrinkage blocks were cut from discs of small radii.

Table 1.—RADIAL AND TANGENTIAL SHRINKAGE VALUES OF RAY AND FIBER TISSUE

Tissue Type	Specimens	Radial shrinkage Per Cent*	Tangential shrinkage Per Cent*	Standard deviation
Radially cut ray tissue	16	2.51	-----	0.58
Radially cut fiber tissue	16	11.97	-----	2.79
Tangentially cut fiber tissue	16	---	14.01	3.59

*Based on green dimensions.

Table 2.—MOISTURE CONTENT AT FIBER-SATURATION POINT OF RAY AND FIBER TISSUE

Tissue type	Specimens	Moisture content at radially determined fiber-saturation point Per Cent	Moisture content at fiber-saturation point tangentially determined Per Cent	Standard deviation
Ray tissue	16	17.6	-----	4.66
Fiber tissue	16	25.6	-----	2.59
Fiber tissue	16	----	30.15	7.79

Summary and Conclusions

The study has clearly shown that radial shrinkage of broad ray tissue in red oak is only a small percentage of that of adjacent fiber tissue. The lower shrinkage of ray tissue may be partially explained by a lower fiber saturation point and density.

It was found that there was no appreciable difference between the radial and tangential shrinkage of fibers. This would suggest that the theory that differential shrinkage stems from differential fibril alignment in the radial and tangential walls is probably not applicable to at least the fiber tissue of red oak.

The shrinkage of gross wood samples was found to lie between the limits determined by the shrinkages of the tissue types. As hypothesized in the ray-restraint theory, the radial shrinkage was only slightly higher than that of the ray cells.

Until the elastic properties of ray tissue are precisely determined the quantitative influence of rays on radial shrinkage will be difficult to determine or illustrate. However, the restraining action of rays as an important factor contributing to differential transverse shrinkage cannot be disregarded.

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Boil Resistance of Blended Urea—Melamine Wood Adhesives

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The effects of various ratios of melamine resin/urea resin on the resistance of plywood to boiling water was investigated. Bonding variables were time assembly, moisture and filler content.

Based on four boil cycles, the performance was roughly proportional to the amount of melamine resin used. Even at 10% melamine resin extension fractional boil resistance was obtained and time assembly was found to be non-critical with regard to shear strength.

I. Introduction

IT IS GENERALLY recognized that the addition of melamine resin to a urea adhesive mix improves the durability of the resulting wood bond. Although considerable data has been published comparing the water resistance and durability of the various types of wood adhesives, the amount of data regarding the adhesive characteristics of melamine and urea resin combinations is surprisingly limited (1, 3, 4, 5, 6, 7, 8).

This report presents the results of a preliminary investigation of the wood bonding characteristics obtained by blending a powdered melamine resin with a liquid urea resin over a wide range of concentrations. The investigation was undertaken to establish basic information and to indicate relative durability. It is not implied that each formulation is optimum.

Except in a few cases, the effect of the exposure to alternating period of boiling in water and drying at 145° F is used as the criterion of bond quality. Although controversial as to its correlation to durability, this method offers a fast, convenient and easily reproduced method for applying severe conditions to an adhesive bond.

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II. Conclusions

1. The resistance of the bond to the cyclic boil and dry test used in this study is almost proportional to the melamine resin content of the mix.

2. For the mixes studied, severe tests showed that maximum properties were not obtained before an assembly time of two hours. Less severe tests did not indicate this fact.

3. The bond was improved by lowering the moisture content of the veneer or by open assembly periods.

4. When the melamine resin/urea resin ratio was reduced to 10/90, the bond was able to withstand short periods in boiling water. Also the effect of assembly time from five minutes to seven hours was minimized.

5. Commercial blends of melamine resin/urea resin in the ratio of 50/50 show uniform shear results under severe tests over an assembly time range of fifteen minutes to seven hours.

III. Experimental Details

A. Mix Compositions: To cover the concentration range, six adhesive mixes shown in Table I were used. A spray dried melamine resin was used in various proportions with a liquid urea resin syrup having an approximate PMMA solids of 60%, and a viscosity of 450 cps. at 25° C. For Mix No. 6, a straight urea resin, the shell flour was modified slightly for viscosity purposes. The difference was later corrected for by adjusting the spread resin solids.

To the base resins, fixed quantities of shell flour and ammonium chloride were added with variable amounts of water to result in fairly comparable mix viscosities and solids contents.

B. Bonding Conditions:

Spread—Approximately 35 lbs./MSGL. Except when noted, resin solids were maintained constant. The veneers were spread with a 26″ rubber covered rolls.

Pressure—200 psi.

Construction—3 ply, 3/16″, 20″ x 20″, all yellow birch veneer construction.

Assembly Time — Closed, Varied from 5 minutes to 7 hours.

Press Time—5 min. @ 240° F.

Veneer Moisture Content—7–8%.

C. Testing: 1. Test conditions for a total of 6 to 8 specimens per test, prepared according to existing standards (2, A, B, C, D) were as follows:

a. Dry Shear
b. 48 hours room temperature water soak and test wet.
c. 3 hours soak at 145° F. and test wet.
d. Cyclic, Room temp. water soak and dry at 145° F.
e. In order to subject the bond to severe conditions, a cyclic boil and dry series was used as follows:

Code	Designation on Figures	Cycle
B 1	4 hr. Boil	4 hrs. in boiling water—cool in water and test wet
B 2	8 hr. Boil	4 hrs. in boiling water—20 hours at 145° F—50 F in air—4 hours in boiling water—cool in water and test wet
B 3	12 hr. Boil	4 hours in boiling water—20 hours at 145° F. in air—4 hours in boiling water—20 hours at 145° F in air—4 hours in boiling water—cool in water and test wet
B 4	16 hr. Boil	4 hours in boiling water—20 hours at 145° F in air—4 hours in boiling water—20 hours at 145° F in air—4 hours in boiling water—20 hours at 145° F in air—4 hours in boiling water—cool in water and test wet

f. Modified boil cycles of less than 4 hours—Samples in boiling water for specified time, then cooled in water and tested wet.

Forty-eight hour soak tests established that full cure of the resin bond occurred in the press and not as a result of boiling water. Except where noted (1 in-

Table I.—BASIC MIX FORMULATIONS—PARTS BY WEIGHT

Mix No.	1	2	3	4	5	6
Melamine Resin A*	100	70	50	30	10	0
Urea Resin B (60%)**	0	50	83.5	116.5	150	166
Pecan Shell Flour	15	15	15	15	15	16.6
Water	55	37	27.0	15	4	0
Ammonium Chloride	0.25	0.25	0.25	0.25	0.25	0.25
Total	170.25	172.25	175.75	176.75	179.25	182.85
Melamine Resin A/Urea Resin B %	100/0	70/30	50/50	30/70	10/90	0/100
% Resin Solids	58.8	58.0	57.0	56.6	55.8	54.6

Bonding Conditions

Spread—Approximately 36 lbs./MSGL. Resin Solids maintained constant.
Pressure—A. Yellow Birch—200 PSI
B. Red Gum and Yellow Poplar—150 PSI
Construction—3 Ply, 3/8", 20" x 20", all veneer construction
Time Assembly—Closed, varied, 5 min. to 7 hours
Press Time—5 min. @ 240°F.
Veneer Moisture Content—7–8%

*Commercial spray dried melamine formaldehyde resin adhesive.
**Commercial liquid urea resin adhesive—PMMA Solid 60%.

stance) all results given here are for specimens boiled for various periods.

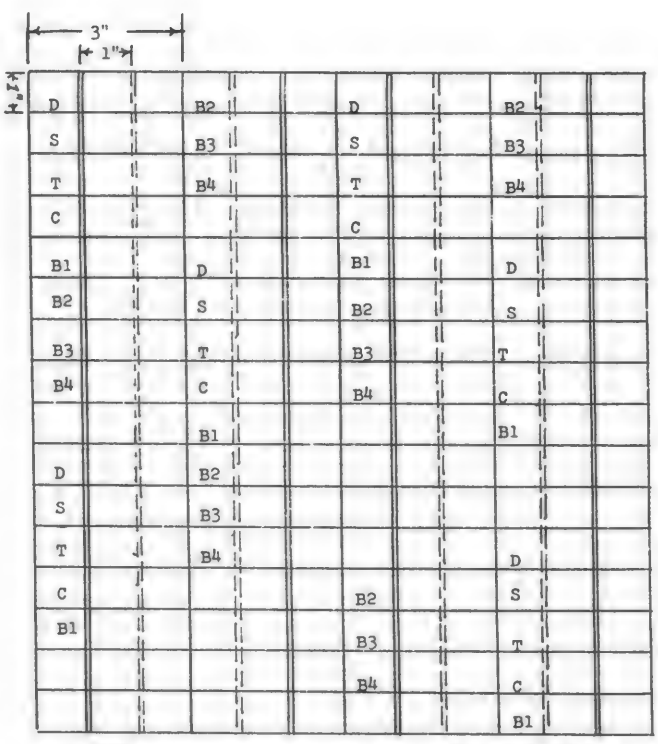
g. Specimen Selection—In order to obtain a true representation of each panel, the test specimens were selected on a randomized basis. The effects of lathe checks were minimized by reversing the kerf cuts for every other test strip. The selection of test specimens and the method of cutting is illustrated in Table II. Specimens were tested in the I. F. Laucks modification of the Riehle shear tester which utilizes water and air pressure for exerting the breaking force.

IV. Conclusions and Discussion of Results

A. Melamine Concentration: Using the average of all panels not showing the effect of short time assembly, Figure 1 shows that an increase in the melamine concentration will result in a more boil resistant adhesive almost in proportion to the melamine resin added. Although the curve for the 70% melamine resin is very similar to the 100% melamine resin, the wood failure shows the superiority of the latter. In order to more graphically represent the effect of melamine on the strength retention,

TABLE II

PANEL & SPECIMEN SCHEME



D - Dry
S - 48 Hour Soak
T - 3 Hours @ 145°F.
C - Cyclic Soak & Dry
B1 - 4 Hour Boil
B2 - 2 Cycle Boil
B3 - 3 Cycle Boil
B4 - 4 Cycle Boil

Figure 2 is plotted using the four hour boil as the base point. This eliminates the erratic drops experienced in the first boil.

Percentages given are for the melamine resin concentration based on total resin as shown in Table I. Although the boil periods are recorded as continuous the specimens were exposed according to the plan shown in the Section III-C-e.

B. Assembly Time: An examination of Fig. 3 and 4 shows that increasing time assembly periods result in an improved shear strength. It is significant to note the 70/30 resin bond shows a uniform shear strength over the entire assembly time range when exposed to a 8 hour boil cycle, but when exposed to a 16 hour cycle boil the effects of assembly time becomes apparent by a loss in wood failure. This, it should be remembered is characteristic of the mix studied. Improvement of the shear strength at the shorter assembly ranges would necessitate modification in the catalyst system, the filler content, and/or the resin.

C. Filler Content: Up to a limit of 20% shell flour no apparent difficulty was experienced either in resin mixing or spreading.

At the short time assembly range, Table III shows the effects of incremental shell flour additions on the bond strength following a 4 hour boil. The use of shell flour to improve the shear strength after boil at the shorter assembly ranges is illustrated.

Based on the 4 hour boil test, it can be concluded that improvement in shear strength at short assemblies time is possible with the use of shell flour.

Table III.—EFFECT OF SHELL FLOUR ON ASSEMBLY TIME SHEAR STRENGTH (PSI)* AFTER A 4 HOUR BOIL

% Shell Flour	Time Assembly (Min.) 15	30	60
0	280– 0	290– 0	340– 0
5	310–10	320–10	380–10
10	360–20	400–20	400–40

*Mix contains 40% Melamine Resin A/60% Urea Resin B Construction 3 ply 3/8 birch spread of 30 lbs./M. S. G. L.

D. Veneer Moisture Content: For the two methods used to study the effects of moisture content on the resin glue bond, it was found that a lowering of the moisture content resulted in an improved shear strength. In Fig. 5 (B) moisture content was varied by conditioning the veneer at different relative humidities. In Fig. 5 (A) the use of an open time assembly which resulted in a lower moisture content as compared to the closed time assembly using veneer conditioned to 7–8 per cent moisture.

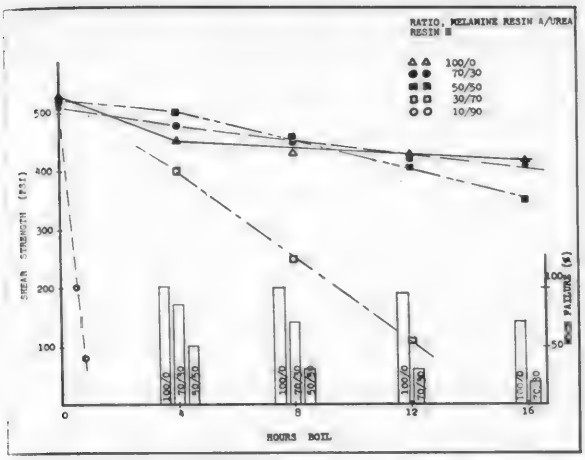


Figure 1 (above).—Effect of melamine/urea ratio on boil resistance of birch plywood.

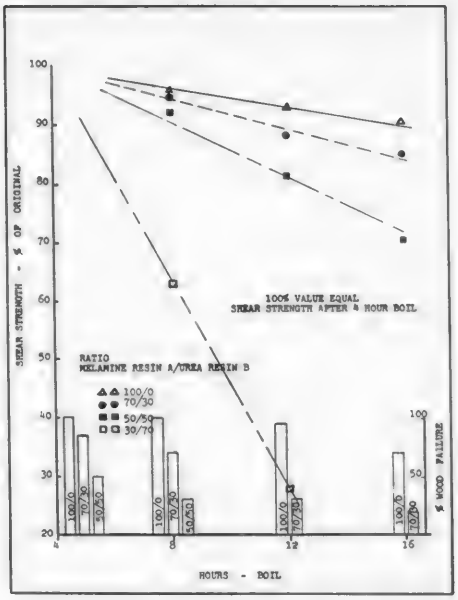


Figure 2 (right).—Effect of melamine/urea resin ratio on boil resistance of birch plywood.

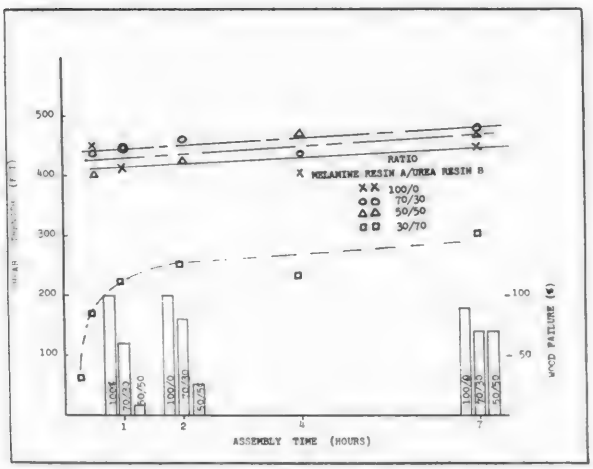


Figure 3.—Effect of assembly time on melamine fortified urea resins, 8-hour boil.

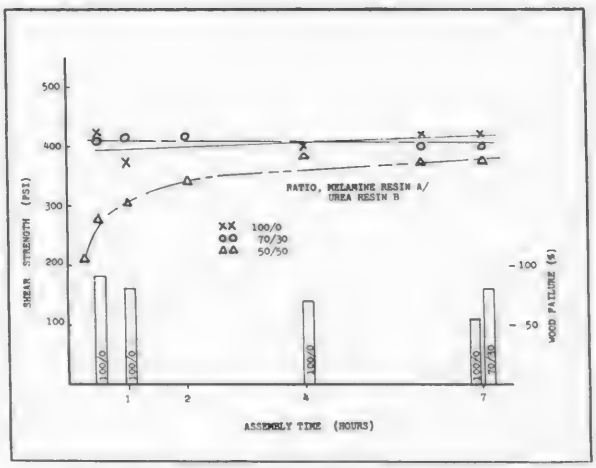


Figure 4.—Effect of assembly time on melamine fortified urea resins, 16-hour boil.

V. Resin Combinations of Low Melamine Concentration

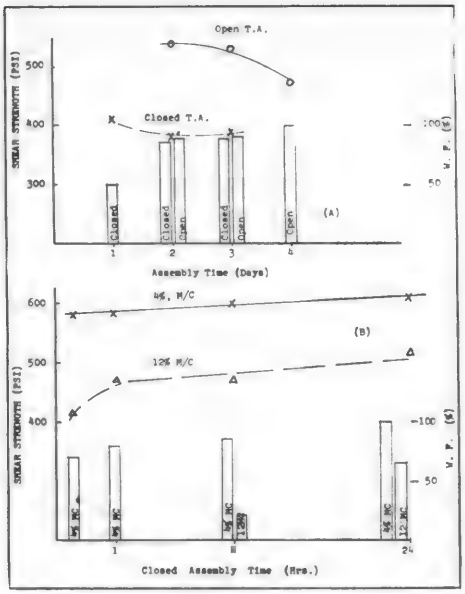
Discussions up to now were concerned with adhesive characteristics of the melamine/urea resins with no attempt to dwell on any one concentration. Completion of this work added to our knowledge of melamine/urea resins as they are being used today, that is, the straight melamine resin, and urea/melamine resins combinations approximating 50/50 concentrations.

It was felt that even in small concentration, melamine resins would contribute desirable properties to the urea bond. To establish this fact Mix 5, Table I, was thoroughly investigated. Advantages were shown which are described in the following paragraphs.

Although test results following the less severe exposure tests (see III-C-1a, b, c, d) are not included they indicate that for all practical purposes no adhesion differences could be found for Mix 5 and an unextended urea resin, Mix No. 6. Based, however, on a cyclic soak and dry test, the incorporation of a small quantity of melamine resin tends to make the assembly time less critical. This is shown in Fig. 6. The catalyst system as used is a simple one, and it is possible that by modifying the system for the straight urea resin a more consistent shear strength could result, but it is almost certain that improvement of one portion of the assembly time range would aggravate conditions at the opposite range.

In terms of boil resistance, low melamine containing Mix No. 5 will not pass any known specification. However, if shorter boil tests can be taken as measures of durability, then the addition of 10 per cent memamine resin will improve the adhesive limitations of a urea resin as shown in Fig. 7. In both cases (A and B), urea bonded specimens were found delaminated at the end of a ½ hour boil period. From both Fig. 6 and 7 the incorporation of 10 per cent melamine resin to a urea resin is warranted in cases when time assembly is critical, and/or incremental improvements in water resistance of the bond are desired.

The experiments described should not be taken as commercial practices but were designed to study the adhesive



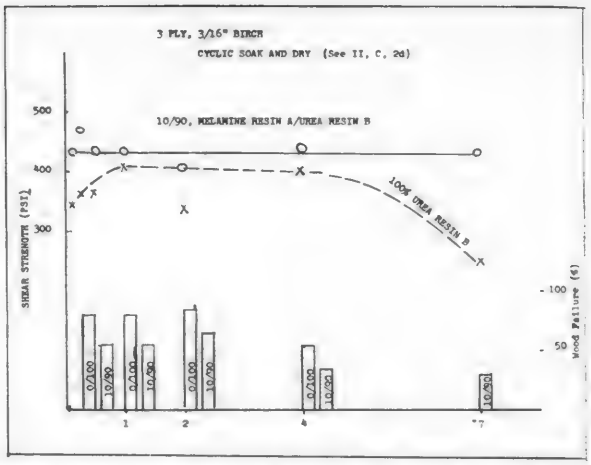
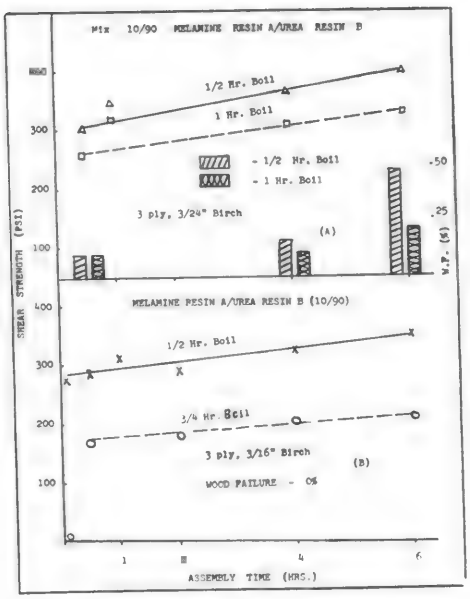

3 PLY, 3/16" BIRCH
CYCLIC SOAK AND DRY (See II, C, 2d)
10/90, MELAMINE RESIN A/UREA RESIN B
100% UREA RESIN B
SHEAR STRENGTH (PSI)
Wood Failure (%)

Figure 5 (left).—Effect of veneer moisture on plywood shear strength.

Figure 6 (above).—Effect of low melamine concentration on plywood shear strength.



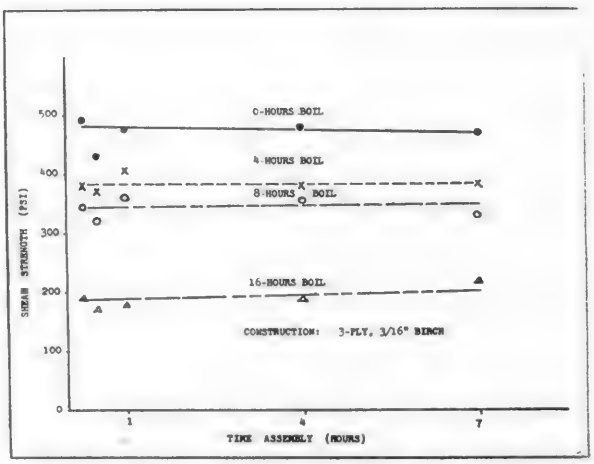


Figure 7 (left).—Effect of construction on shear strength of low melamine fortified urea resins.

Figure 8 (above).—Performance of commercial melamine/urea resin blend. 50 percent melamine resin; 50 percent urea resin.

bond. Birch was chosen because of its high strength and density. Although not shown, constructions using less dense wood will show higher wood failure.

The tests used were extreme to show up differences in performance. This was particularly noticeable in the cases where the effect of the assembly time did not show up until the second or third four-hour boil cycle.

Figure 8 shows how current commercial formulations are designed to give good time assembly ranges even when judged by as severe a test as the 16 hour boil test.

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Advances in Polyvinyl Acetate Glues For Woodworking

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A discussion of the development and use of vinyl acetate resins and vinyl acetate copolymers for the woodworking field from their earliest beginnings up to the present time. An outline of the use of polyvinyl acetate in solution form, and the subsequent development of emulsion technology which led to the widespread use of these resins in joint assembly for furniture manufacture. Reasons for the rapid growth of the copolymers of polyvinyl acetate are also discussed.

VINYL RESIN ADHESIVES are relative newcomers to the woodworking trade, representing the development of new synthetic materials that filled the gap which occurred due to the shortage of animal and protein adhesives during, and immediately following, World War II. The enormous demand for adhesives to be used in military packaging during the war years had to be met by materials possessing greater speed, strength and durability to meet the extreme service demands of far flung military operations. These new synthetics did the job admirably. It was logical that these remarkable resins be introduced into new fields previously dominated by glues of natural origin.

Early History of Polyvinyl

As early as 1937, (6)[1] polyvinyl acetate began to be examined as a possible adhesive material for absorbent surfaces, ranging from paper to leather, building materials, and wood. Prior to this time, polyvinyl acetate was known largely in the form of a solid resin, or as a solution of the solid resin in solvent, and had been in use as an impregnant for wood, (5) a thermoplastic cement for a wide range of surfaces, and as an ingredient in finishing materials. Needless to say, the solid and solution forms gave little promise as production adhesives due to the fact that their setting rate was completely dependent upon the evaporation rate of the solvents employed, and was further influenced by the fact that films deposited from solvent solution had a tendency to retain solvent within the film over a long period of time. The latter fact induced a softening which materially impaired the adhesion of the surfaces, especially under conditions of elevated temperature.

The first practical adhesives based on emulsions of polyvinyl acetate were produced in 1939 by National Adhesives, and as early as 1940 similar formulations were submitted to the Forest Products Laboratory at Madison for Government tests in gluing waterproof kraft shipping containers. (8) Since that time the technology of polyvinyl acetate copolymer emulsions has expanded with amazing swiftness.

Advantages of Emulsion Form

The introduction of the emulsion form of polyvinyl acetate freed the user from the need to adjust evaporation rates of solvent, and opened up a completely new field of adhesive technology based on resin emulsions.

To understand polyvinyl resins in their adhesive use, it is necessary to have some grasp of the theory of emulsions and why they operate as they do.

An emulsion of a resin consists of tiny particles of the resin suspended or dispersed in water, and kept in uniform size and degree of distribution by means of carefully selected emulsifying agents. Emulsifying agents are materials which are mutually soluble in both the resin and in the liquid phase of the emulsion. If you sample an emulsion at random, the sample will reveal, under the microscope, a range of particles microscopic in size, yet uniform in their structure and in their relative distribution.

When an emulsion is placed on an absorbing surface, the aqueous phase is drawn by capillary action into the structure of the absorbing surface, leaving behind the tiny particles of resin. These particles then fuse together with great rapidity to form the adhesive film.

As can be drawn from the foregoing, the setting speed of emulsions depends upon 2 important factors. Firstly, the nature of the emulsion, and secondly, the absorbing capacity (i.e., the rate at which the absorbing surface can take up water), and is relatively immune to outside influences, such as temperature, humidity, pressure, etc.

Polyvinyl acetate emulsions were first introduced to fill the need for high speed packaging materials, (2) and as such were unique when compared to the materials previously employed in that field, displaying phenomenal setting speeds, extremely high strengths, and resistance to the influence of moisture vapor, the effect of greases and oils, and also displayed remarkable tendency to adhere to practically any absorbing medium.

Adaptation to Wood

With the need for similar speed in furniture assembly plus the war-time shortage of protein and starch glues, then in wide spread use for the manufacture of furniture, it was natural for the adhesive manufacturer to explore the possibilities of employing vinyl acetate emulsions for the bonding of wood. The initial introduction of these materials, on an experimental basis, occurred, to the best of our knowledge, in 1943. The initial reaction to these adhesives was overwhelming. The fast-setting effect was unbelievable to people who had previously employed hot and cold solutions of animal glue. Before the field could be explored properly, consumer pressure literally forced many manufacturers into supplying what were then limited quantities of vinyl acetate emulsions for joint assembly of furniture, and the preparation of dimension stock.

Coincident with the introduction of these resins, there was an unprecedented

[1] Numbers in parentheses refer to literature cited at the end of this paper.

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consumer demand for furniture, a serious shortage of skilled employees, seasoned lumber, and as has been stated before, a shortage of both adhesive materials and the technology surrounding their use. All the above factors contributed to serious troubles which followed the too rapid introduction of this new material into the furniture industry.

A few adhesive manufacturers were then investigating and have continued extensive exploration of the working properties of these materials in respect to the preparation of the emulsion itself, and the chemical composition of the basic resin used.

Within a matter of a few short years, the technology of the manufacture and use of vinyl acetate adhesives has overcome many of the earlier deficiencies present in these materials and has yielded a material capable of producing durable joints, available in unlimited quantities for the woodworking trade.

Development of Setting Speed

The most important feature of polyvinyl acetate emulsions is their rapid setting speed when contrasted to materials previously used for joint assembly. Without the use of auxiliary curing methods such as radio frequency generators, hot presses and strip heaters, emulsion adhesives produce workable bonds on most species of North American woods within periods often as short as 20 minutes.

One of the best comparisons of rate of strength development can be found in a thesis prepared by George McSwain at Yale University in 1949. (3) McSwain compared the setting rates of 4 well-known vinyl emulsions to animal glue. Yellow birch veneer lap-joint specimens were employed and the dry shear was taken over a period of 180 minutes. The initial wet strengths of emulsions and animal glue were found to be approximately the same for the first minutes of the experiment. However, within 10 minutes, the emulsions tested displayed better than twice the strength of the animal glue, and at the end of the first hour the emulsions showed a range from 550 psi. to 750 pounds as contrasted to 400 pounds for the animal glue. It is clearly evident from a test of this nature, which has been duplicated many times in our adhesive laboratories, that there is a definite factor of safety in joint strength for handling purposes between assembly joints prepared with emulsion adhesives, over joints prepared with animal glues.

Tolerance to Clamping Variance

In addition to this, studies have been made employing block-shear specimens to determine the influence of clamping pressure on joints prepared with both vinyl acetate copolymers and animal glue.

In a report prepared by Dr. J. S. Bethel and R. A. Moore at North Carolina State College (1) tests were made employing pressures of 10 psi. and 150 psi. on maple block-shear specimens prepared with hot animal glue and vinyl copolymer emulsion glues. At 10 psi., it was shown that the average shear strength of the vinyl resins tested were respectively 3,817 and 3,273 psi. in dry shear, contrasted to a dry shear glue of 1,349 psi. for animal glue.

The results obtained were significantly different at 150 psi. The vinyl emulsions producing dry shears of 3,553 psi. and 3,647 psi., with 3,694 psi. for the hot animal glue.

The above results give some indication of the advantages of employing vinyl copolymer adhesives in joint assembly. It is seldom possible to maintain clamping pressure for a prolonged period of time in ordinary production work. Depending upon the nature of the fit of the joint, internal pressures will range from zero between the joint faces to several hundred psi. It is necessary, therefore, to employ adhesives which will perform well at both low and high clamping pressures. There is an increasing tendency in the woodworking trade to allow the joint in effect to produce its own clamping pressures; that is to say, produce a joint having a sufficiently snug fit to maintain alinement of the surfaces glued, even without glue being present.

Under these conditions, we can assume that pressures are at least in excess of 5 psi. and may be as high as 100 psi. between the joint faces. The use of such a joint is restricted by the natural tendency of an extremely tight fitting joint to remove the glue applied due to the wiping effect when the joint is assembled. Since such joints are in common use, however, they are often made with vinyl emulsions to allow a wide margin of safety, regardless of clamping pressure.

Overcoming Plastic Flow

Many of the early difficulties experienced with polyvinyl acetate emulsions appear to have been caused by the inability of the adhesive to withstand continuous loading (creep). This problem has been approached from several directions. Persons who are interested in the degree of creep measurements have employed mechanical methods of loading the joint to a known value. Various systems have been used, ranging from dead loaded lever arms to constant pressure maintained by hydraulic testing machines, or screw pressure transmitted and maintained by means of calibrated springs, etc. In addition to this, experiments have been conducted in the past by the Forest Products Laboratory (9) and others by preparing panels glued with a variety of adhesives and exposing these panels to alternating cycles of temperature and humidity with a view towards introducing natural wood stresses in the glue line.

To illustrate how research in vinyls has contributed to their widespread application in the furniture industry, I would like to cite two examples from the experience of my own company.

In the first case, the early vinyl adhesives tested were shown to have deficiencies in respect to their ability to withstand the influence of continuous loading and elevated temperatures regardless of how the loading was accomplished. It was clearly felt by National Adhesives that these and other early difficulties could be overcome by a revamping of the resins employed. As a result, six years ago the first of the vinyl acetate copolymers was introduced to the woodworking trade by National Adhesives (7). This particular copolymer has met with very wide acceptance in the woodworking trade, primarily as an assembly glue and also as an adhesive for the lamination of wood under such specialized conditions as vacuum-bag molding and the bonding of high-pressure laminants to wood. This specific vinyl acetate copolymer is distinguished by its exceptional resistance to cold flow or creep under elevated conditions of both temperature and loading. Through a careful choice of emulsifying techniques, the setting speed of this unique copolymer represented a marked increase over the very rapid setting speed of polyvinyl acetate based adhesives, and as a result became the standard reference material for our laboratories in developing new vinyl copolymer adhesives for the woodworking trade.

Low Temperature Sensitivity Corrected

In the second case, we discovered that the vinyl acetate copolymer in this formulation, while remarkably successful in the woodworking trade, had a serious drawback from the standpoint of shipping on the part of the manufacturer, and storage on the part of the user. Like most polyvinyl acetate emulsions, this material was sensitive to low temperatures in storage. It was quite often coagulated and rendered unfit for use by exposure to temperatures under 40° F. In this regard, it was not unique since all other emulsion adhesives then in use also suffered from this deficiency. In the winter months, it was necessary for our firm to maintain extensive facilities for shipping by heated truck, and

the introduction of the material into many plants was impaired by the need for storing this adhesive at temperatures above 40° F.

Development of Improved Copolymer

Three years of intensive research and development have produced a new copolymer.[2] This resin represents a further improvement over its predecessor in setting speed, resistance to elevated temperatures and loading, easy machinability, and is completely freeze-thaw stable. This unique property of resistance to damage by repeated freezing and thawing now makes the wide spread use of vinyl copolymer emulsion adhesives a certainty.

These results were confirmed by the North Carolina State College Wood Products Laboratory (1) by alternately freezing and thawing this formulation prior to gluing for two cycles and testing in dry shear. The results obtained indicate, and have been confirmed by our laboratories on many occasions, that for some, as yet unknown, reason freezing and thawing this emulsion is beneficial in regards to strength values obtained in dry shear.

The unfrozen emulsion had an average dry shear strength of 3,495 psi. and after two cycles of freezing and thawing an average strength of 4,144 psi.

This property represents a definite safety factor on the part of the user, and insures against damage of the adhesive during shipment and storage, thus protecting the user from the possibility of inadvertently using a frozen emulsion. In addition, this particular product can be used at shop and material temperatures as low as 50° F.

The Rapid Setting Factor

The rapid setting speed of this copolymer, coupled with its ideal viscosity for machine application, has brought about many changes in the operation of those furniture plants which have adopted its use.

This material is ideally suited for use in pressure applicators, both the hand operated and the compressed air type, for the positive injection of glue into dowel holes, into grooves, corners, for blocking purposes, and into many other locations in furniture joints.

Rapid setting speed coupled with the relatively small influences of clamping pressures between 10 and 150 psi., permits assembly of furniture with only brief clamping cycles, prior to passing the piece to the next succeeding operation.

In addition, the exceptional bond produced by the particular copolymer between high pressure laminants and wood surfaces has led to a revision of operations in a number of plants that heretofore had employed catalyst activated resins or casein glues in the production of dinette tables, sink and counter tops, and plastic faced furniture (4). It is now possible to schedule goods in a flat laminating operation by gluing stack-wise, followed by a short press cycle and then removing the goods from the press. Additional bond strength develops without the need for baling. In this way the efficiency of the press is increased by the number of I-beams removed from the bale. The labor charges for the handling of the retainer clamps and the unfinished bale are reduced. The efficiency of the operation has even impressed those firms which were equipped with single- and double-opening hot presses to accomplish the same thing. The press time is as short as 15 minutes for a bale, thus coming very close to the production capacity of a double-opening hot press, without the attendant expense of glue preparation, operation and investment charges.

As can be seen from the foregoing, the development of polyvinyl adhesives has followed a pattern not unique in the marketing of new chemical developments. One by one, the initial limitations of a new material have been set aside to make the benefits of American chemical technology available to industry.

The astounding growth of polyvinyl adhesives has been due largely to the fact that they are very fast setting, high strength materials, they are ready for use, they bond to a wide variety of materials including wood, high pressure laminants, etc. Each year, literally millions of furniture joints are bonded with vinyl adhesives.

The new vinyl copolymer products are completely freeze-thaw stable, have good heat resistance under loaded conditions, and make possible high speed furniture production. They have set the pace for the advancing technology of the woodworking industry.

[2] U. S. Patent applied for.

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Discussion

R. Gill (Peter Cooper Corp.): I would like to say that we in the animal glue industry are complimented that our product has been selected as a standard by which other adhesives are measured. I would also like to ask Mr. McCormack—Has the property of creep or cold flow in vinyl type resins, which is brought about by loading or heat, been eliminated?

Mr. McCormack: I would like to make a distinction between polyvinyl acetate emulsions used for wood working and the newer vinyl acetate copolymers. Whereas the former materials were often unsatisfactory from the standpoint of resistance to load at elevated temperature and thus were possessed of certain short comings which minimized their acceptance in industry, the vinyl copolymers have replaced the earlier resins due to their ability to withstand high proportional loading at temperatures well outside of the range that furniture and wood products may be expected to be exposed to in normal manufacture, shipment and service. It is this distinction in terminology and physical properties which should be brought to the attention of the entire industry. Namely, a proper understanding of the differences will prevent confusion of the facts and lead to intelligent use of these new materials.

Evaluation of Glues and Glued Products

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Both the initial quality of a glue joint and its durability under expected service conditions must be considered in selecting a woodworking glue. Factors that cause glued joints in wood to deteriorate include moisture, heat, microorganisms, and mechanical stresses that develop as a result of dimensional changes in the wood. Methods now available for evaluating the durability of glued joints include long-term exposures of controlled conditions and to weathering, actual service tests, and accelerated durability tests. The advantages and limitations of each of these methods is reviewed with typical examples. There is a great need for further coordinated service testing and the development of more reliable accelerated durability test methods for glues and glued products.

Introduction

INTERESTING NEW wood products are being introduced to the public every day. News items feature laminated baseball bats or bowling pins, outdoor furniture, do-it-yourself items that the handy man can make of plywood, huge naval vessels, small boats, and modern furniture with pleasing molded curvatures—all of wood. Usually no special mention is made of the glue or the gluing process involved; apparently gluing is assumed to be simply another step in production, like seasoning, machining, or finishing.

Fortunately, information is available that enables the glue user to select a glue suitable for the expected service and to use it so that satisfactory joints are consistently obtained. In a number of cases, however, premature enthusiasm over a new, incompletely evaluated woodworking glue has resulted in its use with unsatisfactory performance of the glued article in actual use; often this tended to discourage the use of that article for a time, regardless of its potential advantages. Plywood itself is probably an example of this. Earlier types of plywood made with nondurable glues were sometimes unwisely used where moisture resistance was required. The failures that resulted caused people to think of all plywood as nondurable and therefore inferior to solid wood, even after newer types of plywood, made with really durable glues, were introduced. The plastics industry has experienced similar problems.

For these reasons procedures are needed for evaluating the new glues being introduced for use on wood. These procedures should evaluate both initial joint quality on different species and in different constructions and performance in typical constructions during years of actual service. Techniques are also needed for checking the quality of a joint made with any glue over a period of time, both from the standpoint of the glue as a raw material, and of uniformity of joint quality from day to day and month to month.

Joint quality will always depend both on the glue itself and on the way in which it is used in the gluing process. This, of course, means that both the glue manufacturer and the glue user are responsible for the quality of the final glued product. Both, therefore, have a stake in the problem of evaluating glues and glued joints.

Several mechanical test methods have been developed at the Forest Products Laboratory and elsewhere for determining the initial dry strength of glue joints in shear, tension, or cleavage (2).[3] These tests are relatively easy to conduct and, when results are properly interpreted, are generally considered adequate. However, attempts are being made to improve the test methods and the methods of sampling, and to apply modern statistical techniques to the work.

The problem of determining the probable performance of various types of glues in different constructions after service in different environmental conditions is much more complex and one that has not received the attention it deserves. Because the various resin and nonresin glues vary in the permanence that they can impart to glued articles, a general discussion of methods for evaluating the durability of woodworking glues is in order. But first let us review the factors believed to be responsible for the degradation of glued joints in wood articles in service.

Probable Causes of Deterioration of Glue Joints

If any glued joint in wood is to remain serviceable in long-time use it must first be properly made; that is, its initial dry strength must be adequate. Regardless of how durable a glue is, by reason of its chemical formulation, the resultant joint cannot be expected to perform well in use unless the initial joint quality is high. For this reason it is important to develop suitable techniques for gluing with each glue and then to keep adequate control over each step in the gluing process.

External Mechanical Stresses: One often sees demonstrations in which a table top or a flush door is suspended across two planks and loaded at the center with an elephant, a small automobile, or a group of men or women. This sort of demonstration is spectacular, but it may not represent service conditions, since external loads of this type are not typical for such glued constructions. Of course, in certain types of glued-wood constructions such as prefabricated house panels, externally applied loads due to snow, wind, or the weight of roofs, may be important and may be an ultimate cause of failure. The impact of balls striking a laminated bat or bowling pin are other examples of externally applied loads. Perhaps the most common methods for evaluating the effect of external loads on glued joints are the conventional shear tests that are applied to glue joints. In these tests, the external

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[3] Underlined numbers in parentheses refer to Literature Cited at the end of this report.

force is applied to the joint by a testing machine. For many glued constructions this type of external stress is not as important as some of the factors to be discussed later.

Internal Mechanical Stresses: When wood picks up moisture from the surrounding air, it swells; when it loses moisture to the air, it shrinks. These dimensional changes go on day after day due to normal variations in atmospheric conditions. In some cases, swelling of the wood may be caused by actual immersion in water. Finishes and other treatments may reduce these effects, but will not ordinarily prevent them. These dimensional changes in wood may cause severe mechanical stresses on the glue joints. Although it is not possible to avoid these internal stresses, the magnitude of these stresses will depend on the design of the glue joint, the species involved, the moisture content of the wood when glued, and the atmospheric moisture conditions in service.

In certain types of joints, internal stresses may be reduced somewhat by proper design and fabrication techniques. These require that the same species be glued together, that the pieces be of very nearly the same specific gravity and at the same moisture content when glued, and further, that this moisture content be as nearly as possible that of the average moisture content to be expected in service. Any piece of wood will swell most in the tangential direction, less in the radial direction, and only very slightly in a longitudinal direction for a given moisture-content change. Mechanical stresses, therefore, can be minimized by gluing surfaces that are parallel and similar in grain, as tangential to tangential, or radial to radial. This type of design is, of course, impossible in gluing plywood.

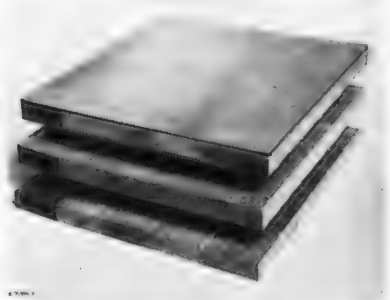

Figure 1.—Delamination in veneered panel caused by dimensional changes in the lumber core from moisture content changes. The edge-glued lumber core is on the bottom. The core in the middle panel was at a satisfactory moisture content when glued, whereas the core in the top panel was too dry and subsequently swelled excessively in service. Cores and veneers were matched and all gluing was done at the same time and under good conditions. Panels were all exposed together.

In certain end-to-side grain joints used as corners in doors or furniture frames such severe mechanical stresses may develop as to make them unsuitable for glued construction without resorting to dowelling or similar mechanical joints. Often a glue joint may be entirely intact, show reasonably high shear strength and high wood failure in initial tests, but later delaminate excessively because of swelling and shrinking of the wood without undergoing any actual chemical degradation of the glue itself. In furniture or other items used indoors in cold climates, joints at first appear adequate and failure may not be observed for several months. When joint failure is observed, it is often attributed to a breakdown of the glue. The actual cause of failure is more likely to be insufficient inherent initial mechanical strength of the joint to resist the internal stresses set up when the moisture content of the wood changes with variations in atmospheric conditions from summer to winter or vice versa. This may be true even though the joints were strong enough to withstand considerable external stresses in processing and shipping.

In tests on glued laminated boat members made with durable-type glues, some joints that gave high shear strengths and nearly complete wood failure in the initial tests delaminated excessively when alternately immersed in water and dried or subjected to high and low humidity conditions; yet there was no evidence that the adhesive was degraded in any way. These findings suggest that these internal mechanical stresses, due to swelling and shrinkage, may be either of a different type or are more severe than the external forces applied in the test machine, even when these latter forces cause nearly complete wood failure in shear. The soaking-drying delamination tests now being used on glued wood products make use of these stresses.

In conventional plywood construction, advantage is taken of the fact that wood changes very little dimensionally in the direction of the grain as compared to across the grain as a result of changes in moisture content. Thus by placing the grain of adjacent veneer plies at right angles to each other, a glued wood product with a much improved dimensional stability is produced. This type of construction, however, puts severe requirements on the glue joints, since the restraining action of the crossbands is effective only so long as the glue joints remain intact. Figure 1 shows a typical edge-glued lumber core and two 5-ply veneered panels with such a core after a few weeks at a high humidity condition typical of summer weather. In the center panel the moisture content of the core was controlled so that it was reasonably close to that in service. In the upper panel the core of the same species was somewhat drier than would normally be desirable. Both panels were well glued with a room-temperature-setting urea-resin glue so that the apparent initial joint quality was adequate. However, exposure to normal room conditions caused excessive swelling of the drier core and delamination of the joint between core and crossband in the upper panel. Plywood subjected to moisture changes will thus produce moderately severe stresses on the glue joint. This accounts for the failure of some plywood under what would otherwise appear to be mild conditions of service.

Figure 2.—Separation of joint in an edge-glued lumber panel caused by swelling-shrinking stresses in the wood due to moisture content changes. Photograph under slight magnification was taken looking down on the upper edge of a glue joint near the edge of a panel. It shows fingering of an elastic glue line under such stress without actual glue separation.

Many conventional types of joints for wood have been designed on the assumption that the glue itself will remain very rigid and inelastic in the glue line and thus hold the two adjacent surfaces rigidly together during the life of the article. This is particularly true for edge-glued joints in solid lumber as in chair seats or table tops. Glues that retain some permanent elasticity in the joint are likely to yield to stresses caused by movement of the wood, and to permit objectionable opening of the joints as noted in figure 2. Such failure may be attributed incorrectly to deterioration of the glue rather than to its elasticity or cold flow. In certain other joints, such as those in furniture assembly work with dowels or mortise and tenons where unusual grain orientations are presented for bonding, such a relatively flexible adhesive may have a distinct advantage.

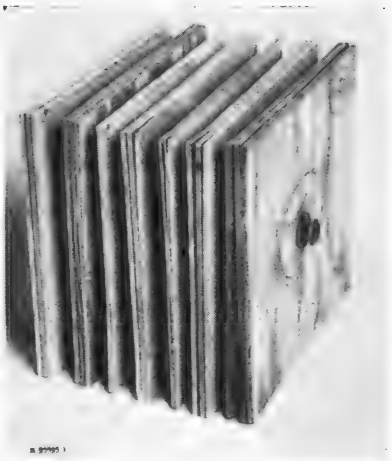

Figure 3.—Delamination in 6- by 6-inch test pieces of plywood of different species and constructions after the two cycles of soaking and drying prescribed for Type 2 plywood in Commercial Standard CS35–49. All panels were glued with a soybean glue under good gluing conditions. From left to right panels were: ⅜-inch yellow birch, ⅜-inch Douglas-fir, 3/20-inch yellow-poplar, ⅜-inch yellow-poplar, 3/20-inch sweetgum, ⅜-inch sweetgum, and ⅜-inch red oak.

Water and Moisture: In addition to the mechanical stresses that result from moisture changes in the wood, a high moisture content may affect the glues themselves. Moisture may soften them, particularly those that exist in a jell-like condition in the joint, as with some of the older nonresin glues, or promote hydrolysis or similar chemical action, particularly with some of the protein glues. Probably very few of the woodworking glues used today are actually water soluble in the cured or hardened condition, but some of them slowly absorb water somewhat as does wood itself. The result is a physical softening and in some cases leaching out of certain components of the glue. The strength of the glue may be reduced so that when some external force or an internal mechanical stress is applied to the glue line while it is moist, failure will take place. These facts are the basis for the conventional panel delamination test used for evaluating plywood according to current versions of Commercial Standards for Plywood (12, 13). In this test 6-inch by 6-inch squares are subjected to a soaking and drying cycle. Glues that are softened by moisture may fail because of internal stresses caused by swelling of the wood in two adjacent plies in opposite directions. Different degrees of delamination in panels of the same 3-ply, 3/16-inch or ⅜-inch construction of several species, all glued with a soybean glue, after two such soak-dry cycles are shown in figure 3. Hydrolysis may occur under some of these moist conditions but it probably takes somewhat longer to become serious than does physical softening of the glue line.

Micro-organisms: When wood reaches a moisture content of approximately 20 percent, a number of microorganisms commonly present in the atmosphere will likely multiply and grow on the wood or on certain glues. They may feed on the glue and thus cause biological degradation of the glue joint. This is especially true for the protein and starch glues or highly extended resin glues. The use of organic preservatives, such as the chlorinated phenols, has been increasing as a means of affording some protection to glue lines against these organisms.

Heat and Cold: Certain types of glues that exhibit definite thermoplastic characteristics may actually be softened if the glued article is used near a source of heat. Small radio or television cabinets or enclosures about radiators or other heating units may show this effect. Slippage of an edge-glued lumber joint, made with a heat-sensitive glue, is shown in figure 4.

Effects of stressing glued-wood joints at subzero temperatures have not been adequately investigated. Limited work (5) on exposure at such temperatures followed by testing at either the low temperature or at room temperatures indicates that conventional woodworking glues are not significantly affected solely by such low-temperature exposure.

Chemical Degradation: Certain chemical changes may occur in any glue line during its service life. These changes may be due to actual degradation of the glue, to further curing, or to related changes resulting from chemical action. Losses in strength in certain glues and types of exposures are best explained on the basis of such chemical changes, although the extent of and the actual mechanisms of some of these degradations have not yet been established. Indeed, in some cases there is some question about whether the decreases of the joint strength observed in tests are due to a chemical change of the glue or to certain other previously mentioned influences.

Heat, which is known to accelerate all chemical reactions, is probably an important factor in reducing the durability of some glue joints in service. Many glue joints in wood are not subjected to excessive temperatures in service. However, interiors of radio and television cabinets are exposed to considerable heat, and exterior parts of buildings, signboards, railway cars, highway trucks and trailers, boats, and bridges may be subjected to both high and low temperatures. Data on actual temperatures of service are limited. Maximum temperatures of 215° F. at Tucson, Ariz., and 179° F. at Madison, Wis., were registered on and under the top skin of wood aircraft wings during the summer of 1943; temperatures above 160° F. were not uncommon during this period (7). Similar studies of temperatures in walls of homes are now being made. Exposure of glue joints in plywood to temperatures of 158° F. or higher may cause significant losses in strength in joints made with urea-resin glues and with certain acid-catalyzed phenol-resin glues within a relatively short time (5). As previously indicated, the mechanism of deterioration is not clearly established.

Some glues are sensitive to certain chemicals present in chemically treated wood, in the glue itself, or in solutions in which the glue joint may be in contact during use. For example, there is evidence that excess acid in certain resin glues may reduce the servicability of joints under rather severe service by an attack on the glue itself. In other types of glues the excess acid or alkali may attack the wood next to the glue line but leave the glue itself unchanged (5, 6, 14). There is little or no evidence at present to indicate that chemicals in normal untreated wood attack any of the conventional glues. Data on effects of wood-treating chemicals on the durability of glues are limited (4). All of these factors need to be investigated further before their import-

Figure 4.—Slippage of an edge-to-edge grain joint in a chair leg, glued with a thermally sensitive adhesive, probably caused by softening of the glue under mild heat exposure.

ance to the durability of glue joints can be properly evaluated. In some cases the apparent reduction in strength under conditions such as heating may be actually due to an embrittlement of the resin glues by excessive cross linking rather than to a chemical degradation of the resin.

Problems in Establishing Durability Test Programs

The rates of deterioration of glue joints in some of the service conditions previously mentioned are quite slow, which is perhaps fortunate for the ultimate consumer of the glued wood product. This is, however, unfortunate from the standpoint of the investigator who must attempt to learn in a short time the probable durability of the different types of glues. At present investigators can get reliable durability data on glue joints only by rather extensive and destructive tests of one of the following types:

(a) Long-term exposures of test specimens to controlled, or partially controlled laboratory conditions;

(b) Long-term exposures of test specimens to actual weathering or other service;

(c) Tests of typical production items in actual service;

(d) "Accelerated" test procedures.

In the above classifications, the term "test specimen" is considered in its broad sense and is not limited to any of the conventional shear- or tension-type test specimens commonly used for evaluating wood glues.

Probably the most generally acceptable test data, from the standpoint of the consumer, would be that from long-time service tests of the actual glued article. To obtain such information before sale of the item would require a delay of several months or years between first fabrication and sale, and would be impractical.

All investigators would prefer to use an accelerated durability test so designed that after only a few hours or, at most, a few days, the long-time durability characteristics of the glue and glue joint would be precisely known. Unfortunately, we are a long way from such reliable and rapid test procedures. Various short-term tests have been suggested or tried. The validity of these tests is always questionable because of the uncertainty as to whether the degrading influence used in the accelerated test is really an acceleration of the same factor causing degradation of the glue joint in service, or is an entirely different influence and therefore of no direct value for the purpose.

Methods must be developed for accelerating the factors believed to be responsible for lack of durability of glue lines, that is, the effects of swelling and shrinkage of the wood, of heat, moisture, micro-organisms, or chemical degradation. Such acceleration will necessarily involve use of higher temperatures, more severe moisture content changes, faster rates of soaking and drying, or higher concentrations of reagents. The question soon arises as to whether such tests then are too severe. The only way to resolve this question is to use reliable long-term test data for comparison. Data on standard test specimens exposed to controlled laboratory conditions and to actual service are desirable.

Exposures of typical glued articles to actual service are important but are not always sufficiently extensive or reliable because conditions of actual service vary from time to time even in one location because of variations in severity of weather, different degrees of mechanical protection of joints, and other factors. The initial quality of the glued joints may also vary considerably in different items. In many cases in the past, this initial quality, and even the type of glue and gluing conditions have not been recorded.

It would be desirable to accumulate accurate long-term service records on typical glued wood products from normal commercial production wherever possible.

It is important to supplement information from service tests with controlled exposure tests on standard glued specimens. The severity of these controlled tests can in turn be checked against the service test experience.

The task of developing new accelerated tests for the durability of glued joints in wood, and conducting both long-time durability tests under controlled conditions and long-time service tests is an enormous one and one in which many people must take part to assure success.

Factors to be Considered in Durability Tests

In planning and conducting any durability tests, a number of different experimental factors must be considered.

Type of Specimen: First a choice must be made between standard test specimens and special specimens made to simulate a particular type of glue joint that is in commercial use. The type and size of construction and the species in the test specimen will, to a considerable degree, determine the type of test condition to be used, particularly in cyclic exposures. Note that the influence under test, be it a certain temperature, degree of moisture, or the presence of a certain chemical, must be permitted to come in contact with the actual glue line. A large, thick specimen, such as a heavy laminate in which the glue lines are a considerable distance from the outside surfaces, must be allowed to remain longer at the high or low temperature, or be allowed to soak or dry longer than would a thin, small specimen, such as one of thin plywood.

Some species absorb or lose water or moisture more rapidly than do other species, as illustrated in figure 3, which must also be considered in selecting the type of cyclic exposure or the length of a continuous exposure. If a test is to emphasize the effects of internal mechanical stresses due to moisture changes, particular consideration must be given to the relative importance of species, ply thicknesses, and cross- versus parallel-grain construction in the specimens. Soaking and drying of any specimen can be accelerated by using vacuum-pressure techniques and special drying procedures such as are now used in the well-known delamination test on laminated construction (3).

Preparation of Test Specimens: Wood must be selected and conditioned before use with a consideration of the type of commercial process to be simulated in the durability test. Generally, it would be desirable to use a species similar to that involved in the actual service. However, since one glue may later be used with a variety of species, it is often desirable to standardize on one of the commonly used species. A rather high-strength wood is preferable, because then the glue joint must be strong in order to exceed the strength of the wood itself; therefore a better evaluation of the actual glue joint strength is possible than with a weaker species. Yellow birch plywood has been used in durability tests at the Forest Products Laboratory primarily because it is a commonly used hardwood veneer species of high strength, and it is relatively easy to select for uniform quality. However, observations on yellow birch are also checked on more limited tests on other species of interest, such as Douglas-fir, yellow-poplar, or sweetgum.

Since primary interest is in the relative performance of the glue joint itself under each of several types of service, it is desirable to make all of the glue joints of the same uniformly high initial quality. Thus, inferior performance later can be assumed to be due to the exposure involved and not to an initially weak joint. To get uniformly high quality joints all of the steps in the gluing process must

be controlled, including the selection of the wood, the conditioning and surfacing of the wood prior to gluing, the mixing and application of the glue, the control of the assembly conditions and temperature, the application of adequate and uniformly distributed gluing pressure, maintenance of this pressure at the proper temperature for a sufficient time, and the proper aging before test. Adequate records must be kept of the details of preparing the specimens.

Sampling Procedure: Sampling is perhaps one of the more difficult phases of the investigation of the durability of glue joints. The statistician may be able to help the glue technologist design experiments that will give results of a high degree of validity with a minimum of tests. It is highly important that the specimens cut from all the different joints be sorted so as to insure that each group of specimens, taken for control strengths and for exposures to various test conditions for the different time intervals, will be equivalent to all others. Generally it is better to make a large number of small glued assemblies, such as plywood panels, over a period of several days and randomize specimens from all such panels for the various test groups rather than to cut all specimens from one or two large glued assemblies made at the same time.

Choice of Exposure Conditions and Test Periods: The choice of the actual exposure to be studied is one of the most difficult to make with certainty. If tests are to involve controlled laboratory exposures, the exposure must be selected to be as severe as possible and yet realistic of service. Particularly if cyclic exposures are involved, special consideration should be given to the type of specimen to be exposed. If weathering or other service-type tests are to be made, the geographical location should be selected after considering climatic and meteorological data with respect to typical service conditions. Data from tests in the Southwest would be of limited value in predicting performance along the Gulf Coast or in New England. Special consideration must also be given to methods of mounting specimens for exposure and to whether specimens are to be protected mechanically as with edging strips, or by coatings, such as paint or plastic overlays. Generally such protection merely delays the effects of the influences being studied and therefore retards attempts to accelerate the test. For this reason it is often desirable to expose test specimens without protection.

It is generally advisable to make a large number of test groups to permit testing over an extensive period of time. In testing modern resin glues with long-term durability characteristics, it seldom happens that too many test specimens are made. More often the specimens under exposure have all been tested before the performance of any one of the glues has been clearly established.

Test Procedure: The actual mechanical test used to evaluate the glue joint both before and after various periods of service is, of course, of great importance. Generally, it would be desirable to use one of the standard types of joint tests, such as the plywood shear specimen or the block shear specimen for this purpose. However, it is often necessary to develop new types of test specimens to simulate the type of joint of interest to a particular investigator or branch of the wood industry. In any case, the experimental factors influencing the precision and results of the new test, such as method and rate of loading, effects of misalignment of load application, or inaccurate machining of the specimen, should be clearly understood before undertaking the tests, as should the significance of that particular type of test in interpreting the results. It is, of course, important to conduct enough tests before exposure starts to serve as a guide in comparing the performance of the joints in subsequent service.

Recent Durability Studies of Glues

Plywood Shear Specimens: Much of the work on the performance of different types of wood-working glues in a plywood construction has been conducted at the Forest Products Laboratory using the conventional yellow birch plywood shear test specimen originally developed there (1). The plywood specimen is used because the cross-laminated construction is typical of a large volume use of woodworking glues at present. Also the mechanical stresses exerted on the glue joint by the swelling and shrinking of plies at right angles to each other with changes in the moisture content of the wood, are typical of a large number of glued-wood constructions. The small-size plywood shear specimen has a definite advantage in much of this work; it is easy to handle, it can be made in large numbers rather inexpensively and then adequately sampled, it is thin enough and small enough to permit rather rapid penetration of heat and moisture to and from the glue lines, and yet it is thick enough to prevent excessive failure in the face when a 1 square inch shear area is used. Large numbers of specimens can be thus exposed in a small space in the exposure test chamber.

The conventional method of studying the durability of glues in such plywood construction at the Forest Products Laboratory is as follows: The desired number of yellow birch plywood panels are glued with each glue under the gluing conditions recommended by the manufacturer or under conditions that have been shown to result in an optimum initial quality joint. Generally a large number of small panels is preferred to only one or two large panels to permit better selection of the veneer and to permit selection of specimens for test from a number of representative panels. After gluing and conditioning, individual test specimens are laid out, numbered, and cut out. Representative specimens from different parts of several panels are then selected for the initial control tests, which consist of dry tests and, for casein and synthetic-resin glues, wet tests after 48 hours' immersion in water at room temperature. The 48–hour immersion test at room temperature is a useful control test to supplement the dry control values. It was originally established for evaluating casein glues after a series of tests at various temperatures and lengths of immersion for this standard plywood test specimen. Either initial dry or wet shear strength may then be used for comparing the performance of the joints in subsequent exposure. The remaining specimens are then sorted into a large number of representative groups for exposure for periods up to 5 years or more under each of the desired conditions. Typical exposure conditions that have been used for such studies include:

1. Continuous exposure to 80° F. and 65 percent relative humidity to simulate the effect of aging under rather mild conditions, generally free from significant mechanical stresses on the glue joint because of dimensional changes in the wood.
2. Continuous exposure to 80° F. and 97 percent relative humidity to test the resistance of the joint to mold and other micro-organisms and to find the effect of moisture content approaching the fiber saturation point of the wood.
3. Continuous exposure to 158° F. and 20 percent relative humidity to check the performance of joints at an elevated temperature that may be encountered in certain conditions of service. Similar tests are being made at 120° and 140° F.

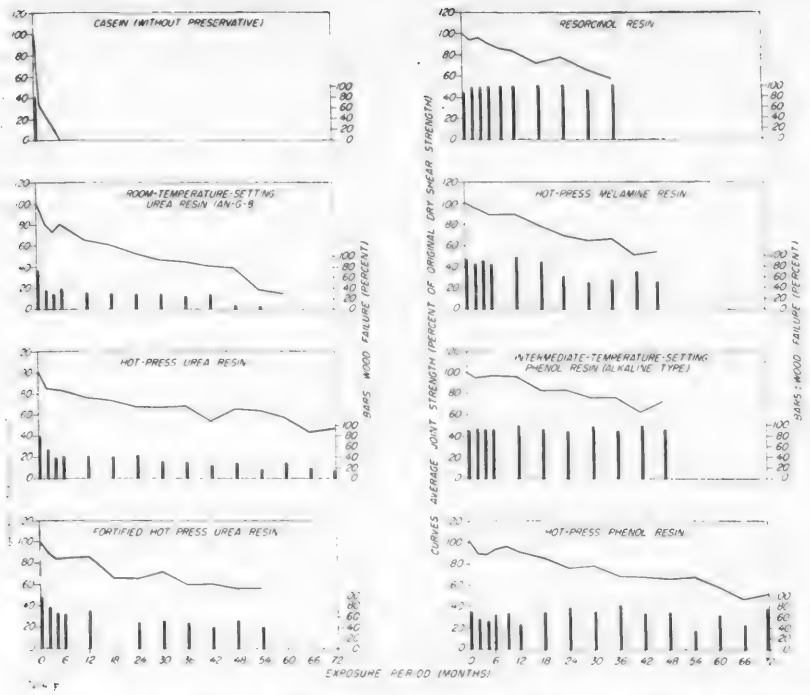
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-6-8
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Figure 5.—Durability of various types of woodworking glues in yellow birch plywood shear specimens, expressed as a percentage of the initial dry strength, when subjected to various periods of a repeating cycle of 2 days' immersion in water at room temperature followed by 12 days' drying at 80° F. and 30 percent relative humidity.

4. Continuous immersion in water at room temperature to indicate the resistance to softening, hydrolysis, or other chemical change.
5. Repeated exposure to alternating soaking and drying, such as immersion in water at room temperature for 2 days followed by 12 days at 80° F. and 30 percent relative humidity. This type of cycle indicates the resistance of the glue to mechanical stresses when the glue is weakened by soaking.

Other exposures include repeated cycles of high and low temperatures (158° to –67° F.), or cycles of high and low relative humidities (97, 90, 80, or 65 to 30 percent relative humidity) may be used. Groups of specimens are then withdrawn from each exposure, usually at 6-month intervals, and tested without reconditioning. The resultant shear test values are commonly expressed as percentages of the initial dry shear strength values. To complete the picture, the actual wood failures observed at the test period under consideration are also recorded. For general presentation (14) these percentages of original dry shear strength retained and the actual percentages of wood failure observed after each period of exposure are averaged for several different glues of each type under test; these average results are presented as shown for one exposure in figure 5. Experience has shown that each of several glues of one chemical type—such as room-temperature-setting, unextended urea-resin glues—performs similarly in the same exposure. Therefore, the practice of presenting average data seems justified, at least for comparing the performance of different types of glues under a given set of exposure conditions.

The performance of various types of woodworking glues that can be used for plywood production have been studied. It is possible to investigate not only the durability of bonds made under the standard conditions commonly recommended by the manufacturer, but under special conditions. For example, high-frequency heating or special hardeners can be investigated.

Laminated Members: A number of long-term tests have been conducted at the Forest Products Laboratory on the performance of parallel-laminated test beams of nominal 1-inch lumber of southern pine, Douglas-fir, red and white oak, and maple. These beams were usually made up to 5 or 6 feet long and with cross sections approximately 7 by 7 inches. Conventional block shear test specimens were then cut from each of the glue lines at one or both ends of the beam and tested initially in the dry condition to serve as controls. The rest of the beam was prepared for exposure by painting one end to reduce moisture content changes and leaving the other end unpainted. Test beams were then given continuous exposure at a high humidity, alternate exposure at a high and a low humidity, or continuous exposure in an unheated storage shed or to outdoor weathering. Each phase in the cyclic exposures to different humidity conditions was selected to produce a maximum moisture gradient from the center to the surface of the beam and thus produce maximum swelling and shrinking at the glue lines. At intervals, amounts of observed delamination were recorded and test sections were cut from each end of the beam. From these sections block shear specimens were cut and tested. The condition of the glue lines in a white oak beam, cured under inadequate conditions, after 4 years of outdoor exposure without protection, is shown in figure 6. Similar beams have been subjected to outdoor service or other severe exposures and the extent of delamination at the two ends, both painted and unpainted, then observed and recorded.

Joints of Plywood to Framing Members: As a part of the early work on prefabricated, stress-covered panel constructions for housing developed at the Forest Products Laboratory about 1935, the performance of three types of glues was investigated in joints of Douglas-fir plywood and Douglas-fir framing members during exposure under each of four repeating high-low humidity cycles. The test specimen, shown in figure 7, was designed to simulate the type of construction used in such stress-cover housing panels. In consisted of exterior-type Douglas-fir plywood panels, 12 by 12 inches in area and ¼ or ⅝ inch thick, glued to nominal 1- by 2-, or 2- by 3-inch Douglas-fir lumber, arranged in a T-shape and glued with each of three glues. The grain of one lumber member was parallel to and that of the other was perpendicular to the grain of the face ply of the panel. After suitable exposure to various humidity cycles, all at 80° F. under

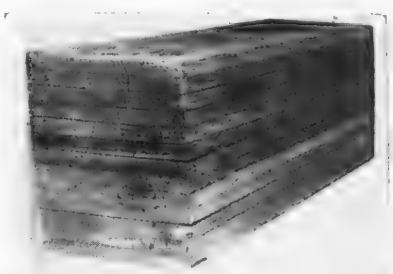

Figure 6.—Laminated white oak beam, glued with a phenol-resin glue under inadequate curing conditions, after about 4 years' exposure to the weather.

laboratory-controlled conditions, a modified block shear specimen was cut from the joints between the plywood and the lumber; however, backing strips were first glued to the side of the plywood opposite the framing member to keep it from failing in compression during the subsequent test. The performance of casein, urea-resin, and phenol-resin glues were established in such constructions. Data in figure 8 shows the relative performance of these three glues in each of four cycles, with each of the two types of joint construction.

Assembly-Type Joints: In a recent study at the Forest Products Laboratory some of the modern synthetic-resin glues and the older nonresin glues were evaluated in furniture-type assembly joints, such as dowel, mortise-and-tenon, block, and slip-type points (11). Joints were alternately subjected to high and low humidity conditions selected as representative of changes that furniture joints are likely to encounter from summer to winter in different parts of the country or as accelerations of such changes. Examples of the types of joints are shown in figure 9. These specimens were tested both before and after exposure to the humidity cycles. Specimens A, B, E, and F were tested by forcing the joints apart in tension with a jig that could be loaded in compression. Specimens C and D were loaded in compression. Modified block shear specimens were cut from specimen G after exposure and then tested in shear.

Three of the cycles used in this work were designed simply to cause internal mechanical stresses. However, the most severe cycle may have also introduced some softening of the glue joint by the moisture in the high humidity phase of the cycle. The three cycles were: (1) 4 weeks at 90 percent relative humidity followed by 4 weeks at 30 percent relative humidity, (2) 4 weeks at 80 percent relative humidity, followed by 4 weeks at 30 percent relative humidity, and (3) 4 weeks at 65 percent relative humidity, followed by 4 weeks at 30 percent relative humidity. All exposures were at 80° F. Cycle (3) was probably most typical of northern climates since the moisture content of the wood would vary from 12 to 6 percent in this cycle. Cycles (1) and (2) were made more severe than cycle (3) by introducing more moisture in the high humidity phase; they might therefore be considered accelerated tests. Results of these tests were interesting in that certain glues, particularly the phenol-resorcinol resin glues, performed unusually well in most joints and definitely better than the conventional ani-

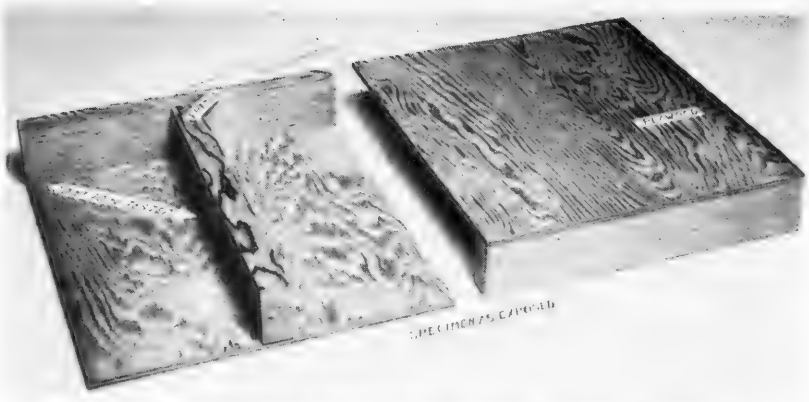

Figure 7.—Test panels of plywood-to-wood framing members to simulate joints in prefabricated, stressed-cover house panels.

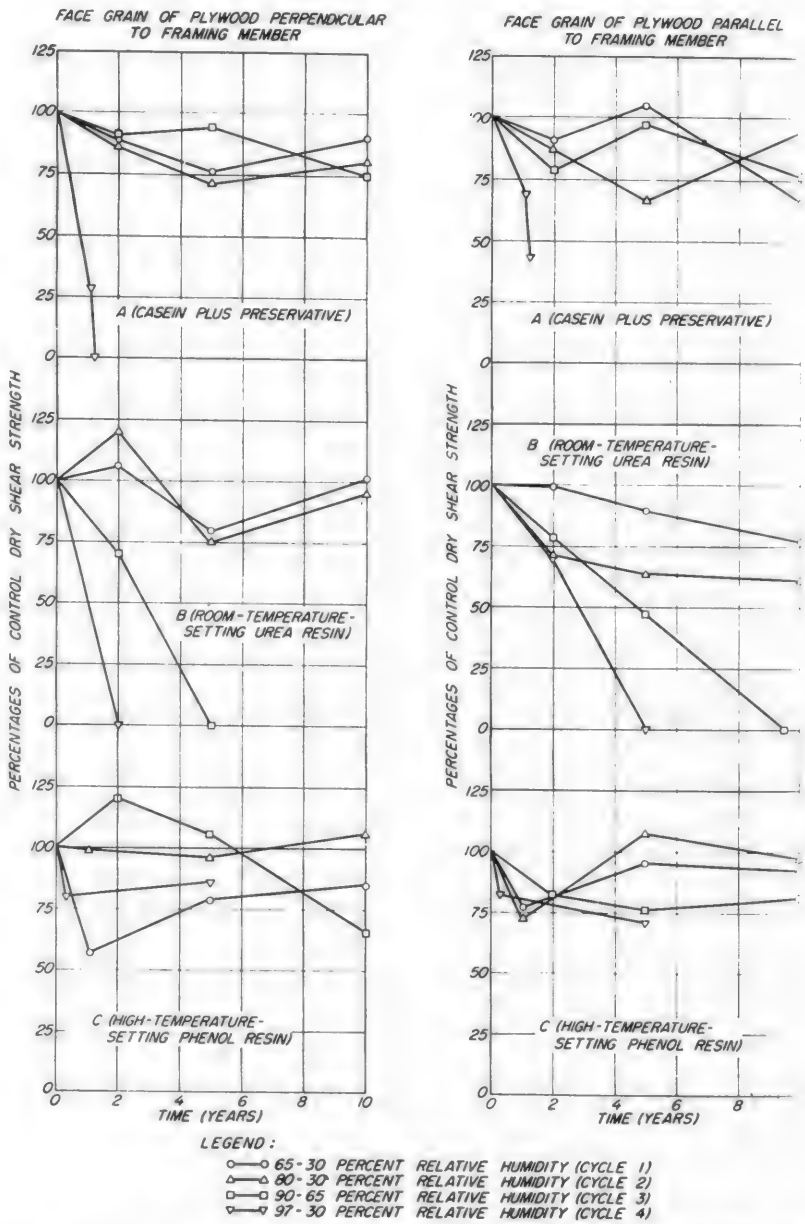
FACE GRAIN OF PLYWOOD PERPENDICULAR TO FRAMING MEMBER
FACE GRAIN OF PLYWOOD PARALLEL TO FRAMING MEMBER
A (CASEIN PLUS PRESERVATIVE)
B (ROOM-TEMPERATURE-SETTING UREA RESIN)
C (HIGH-TEMPERATURE-SETTING PHENOL RESIN)
PERCENTAGES OF CONTROL DRY SHEAR STRENGTH
TIME (YEARS)
LEGEND:
65-30 PERCENT RELATIVE HUMIDITY (CYCLE 1)
80-30 PERCENT RELATIVE HUMIDITY (CYCLE 2)
90-65 PERCENT RELATIVE HUMIDITY (CYCLE 3)
97-30 PERCENT RELATIVE HUMIDITY (CYCLE 4)

Figure 8.—Shear strengths of glue joints between plywood and framing members after various periods of exposure to one of four repeating cycles of high and low relative humidities at 80° F.

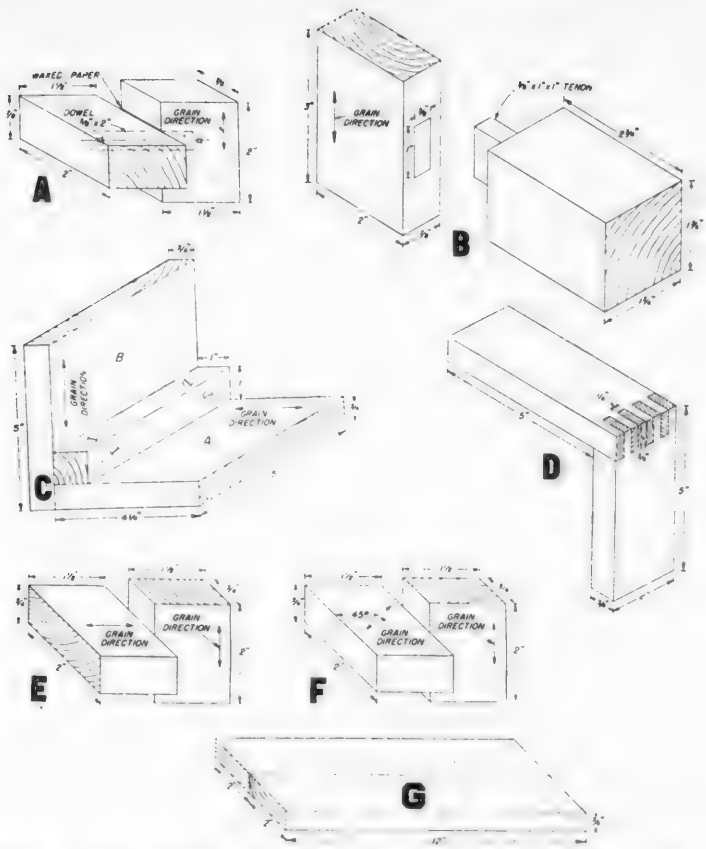

Figure 9.—Various types of joints used for evaluating glues for assembly gluing: A, dowel; B, mortise-and-tenon; C, blocked corner; D, slip or lock; E, end-to-side grain; F, 45°-to-side grain; and G, side-to-side grain.

mal glue normally used for such applications. Some of the glues were promising in certain types of joints and not in others. The results of such tests supplement the conventional types of durability information developed on plywood and laminated members.

Long-Term Exposure to Weathering: Exterior weathering is an uncontrolled exposure, subject to considerable variation over a period of time; results in one location may be different from those in another location. Nevertheless, exterior weathering represents a useful service test. To serve as a guide and possible standard of service under severe conditions, a program of exposure of plywood panels to exterior weathering was begun at the Forest Products Laboratory in 1936 and has been continued since that time.

To compare the performance of different glues in plywood construction, a series of panels was prepared with each glue. Usually panels approximately 24 inches square were prepared of each of three species—yellow birch, yellow-poplar, and Douglas-fir—and each of two constructions—three-ply 3/16-inch and five-ply 5/8-inch. Duplicate panels were made for each variable. These species permitted an evaluation of glues on a typical softwood and on a medium- and a high-density hardwood. The two constructions offered considerably different magnitudes of stresses on the joints. The thinner panels usually were subject to greater warping and cupping than the thicker panels and also probably underwent greater and more rapid changes in moisture content of the plies during exposure than did the thicker panels. However, the thicker panels may have developed greater stresses on the glue joint.

After gluing, conditioning, and trimming, one 18- by 18-inch section was cut from one corner and the rest of the panel was cut into conventional plywood shear-test specimens. Representative groups of these specimens were tested dry and wet after 48 hours in water at room temperature. Specimens were also tested after one or more of the short-term exposures being considered as accelerated tests for later reference. These short-term tests were usually similar to those now used for evaluating glue joints in plywood in the Commercial Standards (12, 13). The 18- by 18-inch specimens were then mounted in a vertical position on a test fence near Madison. Panels face to the south and have no paint or mechanical protection. A typical installation is shown in figure 10. Panels are being inspected at intervals and the amounts of delamination at the edges and the percentages of open joint area due to glue failure are recorded. Results are expressed as glue joint integrity ratings from 0 to 100, with 100 indicating no delamination. Typical data from this method of rating are shown in figure 11. In this figure, joint integrity ratings represent the average for all three species and both constructions for each type of glue. A more recent method of evaluating the glue joint integrity of these panels involves the probing of each glue line with a narrow feeler gage to plot the actual areas of open glue joints between plies. The areas thus plotted on a suitable form have then been measured by means of a planimeter, and the areas of delamination have been reported as percentages of the total panel area.

The performance of the less durable glues, such as casein glues, may be significally different on the various species of veneer when subjected to outdoor exposure. The behavior does not seem to be related exclusively to density of the species, but seems to depend in part on other properties, such as the rapidity with which moisture is absorbed or released and the natural resistance of the wood to decay organisms. For example, a special series of panels of a number of different species were glued with one casein glue and exposed to the weather in Madison for a 3-year period; joint integrity ratings of 81 on western redcedar, 58 on Douglas-fir, 20 on yellow birch, 2 on black tupelo, 5 on cottonwood, and 0 on red oak, ponderosa pine, and white fir were obtained. Similar panels glued with a phenol resin showed integrity ratings from 82 to 98 on these same species after this 3-year period of exposure. Note that the plywood exposures mentioned here involve no protection for the wood or the glue lines. If plywood panels or other glued products are protected with paint, other finishes, or mechanical protection, the exposure test is no longer an evaluation of glue joint alone but of the effectiveness of this protection. Obviously such protection will delay the action of the degrading influences on the glue joint and on the wood. This, then, lengthens the time in which the relative advantages of the glues become apparent.

Plywood durability tests under outdoor weathering conditions have also been investigated by workers at the British Forest Products Laboratory at Princes Risborough (9) and by the

Douglas-fir Plywood Association in their testing on the West Coast (10).

Accelerated Durability Tests: So-called accelerated durability tests would have a distinct advantage in time saving over the long-term tests. At present no entirely adequate short-term test is known, although some of them seem to fulfill useful purposes, and various investigators are attempting to develop more adequate tests. The actual scope and limitations of some of these so-called accelerated tests are often misunderstood and are worthy of some comment.

Boil Tests: A number of current specifications for glues or for glued joints in plywood contain a boil test or a boil-cycle test that is applied to a conventional plywood shear specimen. The best known of such tests is a cycle of 4 hours of boiling followed by 20 hours of drying at 140° F., then a second 4-hour period of boiling. Specimens are then cooled to room temperature and tested while wet. Such boil tests are only reliable when the type of glue is known. There are indications that certain types of glues may withstand such a boiling process, yet fail on prolonged exposure to weather. Another limitation of boil tests is that the boiling tends to advance the cure of certain incompletely cured resin-glue joints and thus improve their strength.

Boil tests offer some interesting examples of the problems always encountered by those attempting to develop an accelerated test procedure. To accelerate the effects that have been shown to reduce the durability of some glues, such as the effects of heat and of moisture, the severity of exposure must be increased. Thus, instead of merely using mild heat or a prolonged exposure in water, the two are combined by the use of boiling water. Cyclic boiling and drying is, of course, intended to produce alternate swelling and shrinkage stresses on the weakened glue joint. Although some may object to such a boiling test as being too severe, since glue joints in service are probably never subjected to boiling water, this type of exposure is necessary to get a truly accelerated test. Whether the test is reliable and representative of actual service must be established by correlating the results with those of longer term tests. The Douglas-Fir Plywood Association has established to its satisfaction that the results of such a boil-dry-boil cycle on specimens of commercial Douglas-fir plywood glued with durable type phenol-resin glues, when properly interpreted, can be correlated successfully with the results of outdoor service tests on their test fence.

Vacuum-pressure Cycles: The vacuum-pressure cycle procedure is most familiar for evaluating glues for laminated construction and for determining the adequacy of the glue lines themselves in laminated timbers. Similar methods have been used for rapidly soaking plywood test specimens for special tests. The technique is, of course, based on the standard impregnation procedures used in the wood-preserving industry. In this test a suitable cross section of a test beam, usually 3 inches along the grain, is subjected to 2 hours of vacuum, 2 hours of air pressure, 2 hours of vacuum, then 2 hours of air pressure. The sample is then dried at specified temperature, humidity, and air velocity conditions for a total of 3-2/3 days. This cycle is repeated two additional times, then the amounts of delamination in the glue lines on the end-grain surfaces are measured and recorded. This test procedure was developed at the Forest Products Laboratory to evaluate the quality of glue joints made with glues of known durability (phenol, resorcinol, and melamine-resin glues) when cured under different curing conditions. It was intended to introduce rather severe internal mechanical stresses on the glue line in certain studies, particularly white and red oak, Douglas-fir, and southern yellow pine. Such stresses are known to be encountered in laminated timbers in marine service when in and out of the water. Studies of this test show that the vacuum-pressure cycle coupled with delamination observations is a reliable method of predicting the ultimate performance of glued laminated ship timbers in service, provided they are produced with durable glues. It should not, however, be inferred that such a short-term vacuum-pressure soaking and drying test is in any way a measure of the ultimate durability of other types of glue joints in actual service, since this test does not simulate the effects of chemical degradation, attack by micro-organisms or long-term exposure to water and moisture.

Effects of Micro-organisms: The resistance of different types of glue lines to the mold and fungi is important in evaluating the resistance of certain protein and extended-resin glues under high moisture content conditions. The resistance of glue lines can, of course, be investigated under long-term exposure to high relative humidity conditions. An accelerated mold test has, however, been developed at the Forest Products Laboratory (8) using sap birch veneers impregnated with a dilute casein glue, then inoculated with a wild mold organism (not cultured or identified). In this test plywood shear specimens are stacked on the moldy veneers and maintained over water in a closed chamber at 72° to 80° F. for 14 to 28 days. The joint quality is evaluated before and after such an exposure.

In studies of the effect of micro-organisms, one might well question the use of an unidentified and wild

Figure 10.—Plywood test fence installation at the Forest Products Laboratory, Madison, Wis.

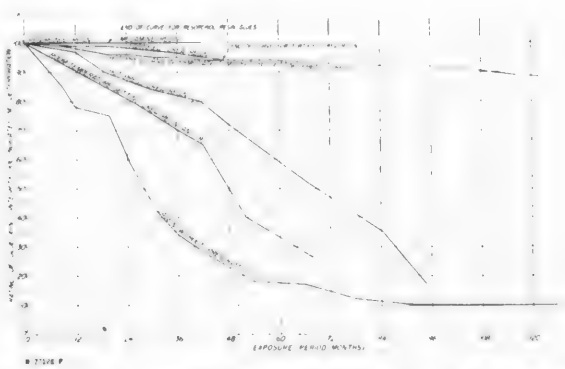

Figure 11.—Relative durability of glued joints in unprotected plywood panels subjected to outdoor weathering. (Values shown are averages for yellow birch, yellow-poplar, and Douglas-fir panels.)

micro-organism instead of a pure culture of a known organism. To effectively use a pure culture, sterile test specimens and sterile conditions would be needed throughout the test, This would enormously complicate the testing procedure for the average wood technician and does not seem to be necessary except for special investigations. Adequate information is not available at present to properly select the type of pure organism to be used for such an exposure test. However, further work could probably be profitably done on the question.

Correlations Between Tests: The short-term and long-term durability studies cited were selected only as examples of different approaches that have been used at the Forest Products Laboratory. A number of other equally interesting and promising studies could have been mentioned. In some cases there have been good correlations noted between short-term and long-term test results. Good correlation has been noted between percentages of delamination in laminated beam sections, glued with phenol-resorcinol- and melamine-resin glues, in the vacuum - pressure soaking - and - drying cycle (3) and in long-term outdoor exposure. There is also reasonably good correlation between performance of glues in plywood in continuous exposures at elevated temperatures and in outdoor weathering in Madison. There appears to be some correlation between performance of glue joints in plywood in certain boil tests and in performance in both severe laboratory-controlled conditions and outdoor weathering. Further correlations are under study.

In addition to the Forest Products Laboratory tests that have been mentioned, a number of others are being considered by various organizations, such as Committee D-14 of the American Society for Testing Materials. There is need for a great deal of new work, new ideas, new methods or better methods of evaluating the durability of woodworking glues under various types of exposure conditions. It is hoped that this discussion will be helpful in crystallizing some ideas on the part of the wood technologists now entering the field and that they will help in developing better long-term and short-term test procedures.

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Gluing Pressure Treated Wood With Resorcinol Type Adhesives

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Describes tests and results using resorcinol type adhesives to bond wood previously pressure treated for preservation. Data resulting from tests are given. In general, bonding of treated wood is not a great deal more difficult than the bonding of untreated wood.

GLUING OF WOOD to improve its utility has been practiced for centuries. It has been expanded from an old art in which non-durable animal glues were used, to a modern day science where many different types of glues are available, most of which form bonds having greater strength than the wood itself. Many of the present day adhesives withstand the most severe type of exposure without deteriorating.

As glues have been improved, particularly with the introduction of resorcinol and phenol-modified resorcinol adhesives, the fields of possible applications of glued lumber have increased. Many of these applications expose the wood to conditions of deterioration by decay, termites, or marine organisms, thereby necessitating the protection afforded by pressure treatment with standard wood preservatives.

In the past few years, plywood for bus or passenger coach flooring, and small glued laminated beams and timbers, have been pressure treated successfully with preservatives. The adhesive bond has no appreciable effect on preservative penetration, and the treatment, even with water borne preservatives, does not affect the strength of the bond.

Many glued structures cannot be handled conveniently in pressure treating equipment either because of: (1) size and shape, or (2) economy of treatment. In these cases, it is desirable to glue after treatment. This paper describes work undertaken to determine what effect pressure treatment of lumber prior to gluing has on the resistance of resorcinol and phenol-modified resorcinol adhesives to delamination in the twelve-day cycle test.

The resistance of the glue bond to delamination was determined in this work by a standard A.S.T.M. D-1101-50T vacuum-pressure test commonly used in the evaluation of adhesives for laminated timbers. The Forest Products Laboratory devised this test to evaluate the resistance of the glue bond to delamination versus the internal stresses arising in timbers subjected to outdoor conditions. However, all detrimental effects to the glue line in actual service such as micro-organisms and external loadings, cannot be measured by this test, and therefore, the results are not to be construed as an exact indication of the effect of outdoor exposure on the glue bond.

Selection of Species Tested

The following species, which represent the major portion of commercially used woods, were selected for testing in this project: red oak, white oak, Douglas fir, southern yellow pine.

All lumber was clear and flat grained with slope not more than 1″ in 20″. It was kiln dried to a moisture content of 12%. Individual pieces were 7/8″ x 5½″ x 24″ and were selected at random.

Preservatives Evaluated

Preservatives used to pressure treat the four species listed above were as follows:

1. Creosote
2. 5% Pentachlorophenol dissolved in No. 2 Fuel Oil
3. Copper Naphthenate dissolved in Stoddard Solvent (1% Copper.)
4. ACC (Acid Copper Chromate)
5. Ammoniacal Copper Arsenite
6. Copperized CZC
7. CZC (Chromated Zinc Chloride)
8. Chromated Copper Arsenate
9. Tanalith

Detailed analyses and compositions of these preservatives appear in the Appendix.

Table I.—PRESERVATIVE RETENTIONS

	Southern yellow pine	Douglas fir	Red oak	White oak
1. Creosote	5.8	9.3	6.0	4.[illegible]
2. Pentachlorophenol*	.28	.40	.33	.[illegible]
3. Copper Naphthenate**	.049	.059	.049	.0[illegible]
4. ACC (Acid Copper Chromate)	1.29	1.28	1.17	.[illegible]
5. Ammoniacal Copper Arsenite	.91	.72	.83	.[illegible]
6. Copperized CZC	1.07	1.03	1.12	.[illegible]
7. Copperized CZC (High Ret.)	2.46	2.22	1.83	1.4[illegible]
8. CZC (Chromated Zinc Chloride)	1.17	1.07	1.28	1.[illegible]
9. Chromated Copper Arsenate	1.27	1.22	.92	.[illegible]
10. Tanalith	.53	.56	.63	.[illegible]

Note: All retentions of water borne preservatives are expressed in pounds per cubic foot.

*Pentachlorophenol retention is expressed as pounds of dry pentachlorophenol per cubic foot, calculated from chlorine analysis. The pentachlorophenol (5 percent) was dissolved in No. 2 Fuel Oil.

**Copper Naphthenate is expressed as pounds of metallic copper per cubic foot, calculated from copper analysis. The copper naphthenate was dissolved in Stoddard Solvent (1 percent copper).

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Treatment and Post-Treatment Handling

All specimens were pressure impregnated in accordance with American Wood-Preservers' Association Standard C 2. (Also Federal Specification TTW 571c) The creosote, pentachlorophenol, and copper naphthenate were applied by the empty cell process while all other (water borne) preservatives were applied by the full cell process. Preservative retentions are listed in Table I.

After treatment, all specimens which had been treated with water borne preservatives were end coated with a sealer to reduce end checking and then were placed in a forced draft dry kiln, where they were dried to a final moisture content of 12–15 percent.

The adhesives chosen for this evaluation were two which have had outstanding performance in several fields. Each adhesive has been used widely in laminations of several species of wood where marine or exterior usage required the utmost in durability of glue line. Adhesive "X" is an unmodified resorcinol formaldehyde adhesive, while adhesive "Y" is a phenol-modified resorcinol formaldehyde adhesive. These are Penacolite* Adhesives G-1124 and G-1260 respectively. While it may be hoped that resorcinol formaldehyde and phenol modified resorcinol formaldehyde adhesives, as a class, will perform similarly, we know from experience that these resorcinol adhesives, like most resins and plastic materials, must be regarded as individuals, and not as a class. Although they are referred to herein by chemical type, we do not wish to imply that all other adhesives of this class will perform equally.

Preparation of Treated Stock for Gluing

Preparation of pressure-treated lumber for gluing was similar to that normally used for untreated wood. In each case, certain basic principles had to be complied with to produce uniform and reproducible results. Laminated test beams were prepared from stock of uniform density using only flat grained lumber. Stock selected for use was conditioned two to three weeks in a constant temperature and humidity room (75° F. and 52 ± 2½ percent relative humidity) to bring the moisture content within an 8 to 12 percent range prior to gluing. Where water-borne preservatives were used, moisture content of the wood was determined by the oven-drying method, while a toluene-extraction test was required for wood treated with oil-borne preservatives.

*Penacolite—Trade-mark of Koppers Company, Inc., registered in U. S. Patent Office.

Table II.—12-DAY CYCLIC TEST RESULTS ON PRESSURE TREATED WOOD BONDED WITH RESORCINOL ADHESIVES "X" AND "Y" FOR 2 HOURS AT 150° F. GLUE LINE TEMPERATURE

Wood Species	Wood Preservative	Lbs./Cu. Ft. Retention	Adhesive "X" % Delamination	Adhesive "Y" % Delamination
White oak	Untreated	-----	0.1	0.4
	Creosote	4.5	4.9	2.1
	Pentachlorophenol	0.37*	4.0	1.0
	Copper Naphthenate	0.04**	0.0	0.0
	Acid Cupric Chromate	0.85	7.7	10.2
	Ammoniacal Copper Arsenite	0.60	2.1	47.1
	Copperized CZC	0.72	0.4	0.5
	Copperized CZC (High Ret.)	1.44	0.1	1.9
	Chromated Zinc Chloride	1.11	3.1	5.4
	Chromated Copper Arsenate	0.78	1.1	12.4
	Tanalith	0.35	1.1	0.9
Red oak	Untreated	-----	0.0	0.0
	Creosote	6.0	5.1	0.0
	Pentachlorophenol	0.32*	0.0	1.2
	Copper Naphthenate	0.049**	0.3	0.5
	Acid Cupric Chromate	1.17	0.8	0.6
	Ammoniacal Copper Arsenite	0.83	0.3	4.5
	Copperized CZC	1.12	1.0	0.5
	Copperized CZC (High Ret.)	1.83	0.0	0.5
	Chromated Zinc Chloride	1.28	0.3	1.1
	Chromated Copper Arsenate	0.92	0.1	2.8
	Tanalith	0.63	0.6	1.4
Southern yellow pine	Untreated	-----	0.0	1.3
	Creosote	5.76	0.5	0.3
	Pentachlorophenol	0.28*	1.5	0.0
	Copper Naphthenate	0.049**	0.0	1.2
	Acid Cupric Chromate	1.29	14.5	22.2
	Ammoniacal Copper Arsenite	0.91	3.7	40.3
	Copperized CZC	1.07	5.0	2.3
	Copperized CZC (High Ret.)	2.46	2.8	9.5
	Chromated Zinc Chloride	1.17	4.0	2.0
	Chromated Copper Arsenate	1.27	3.7	2.3
	Tanalith	0.53	2.6	0.4
Douglas fir	Untreated	-----	0.0	0.0
	Creosote	9.3	0.2	0.8
	Pentachlorophenol	0.40*	0.8	0.2
	Copper Naphthenate	0.059**	0.0	0.0
	Acid Cupric Chromate	1.28	0.3	3.2
	Ammoniacal Copper Arsenite	0.72	1.6	24.9
	Copperized CZC	1.03	0.3	1.2
	Copperized CZC (High Ret.)	2.22	0.9	2.1
	Chromated Zinc Chloride	1.07	0.4	0.0
	Chromated Copper Arsenate	1.22	1.0	0.0
	Tanalith	0.56	0.2	0.3

*Expressed as pounds Pentachlorophenol per cu. ft. calculated from chlorine analysis.
**Expressed as pounds metallic copper per cu. ft. calculated from copper analysis.

Table III.—INCREASED CURE TIME ON LAMINATES IN TABLE II THAT EXCEEDED 10 PERCENT DELAMINATION (GLUE LINE TEMPERATURE 150° F.)

Wood Species	Wood Preservative*	Cure Time	Adhesive	Percent Delamination
White oak	Acid cupric chromate	6	Y	0.83
Southern yellow pine	Acid cupric chromate	6	Y	4.8
Southern yellow pine	Acid cupric chromate	6	X	9.6
White oak	Ammoniacal copper arsenite	6	Y	11.2
White oak	Ammoniacal copper arsenite	10	Y	7.0
Southern yellow pine	Ammoniacal copper arsenite	6	Y	42.2
Southern yellow pine	Ammoniacal copper arsenite	10	Y	21.0
Douglas fir	Ammoniacal copper arsenite	6	Y	3.75
White oak	Chromated copper arsenate	6	Y	5.9

*Retention of the preservative is shown in Table II.

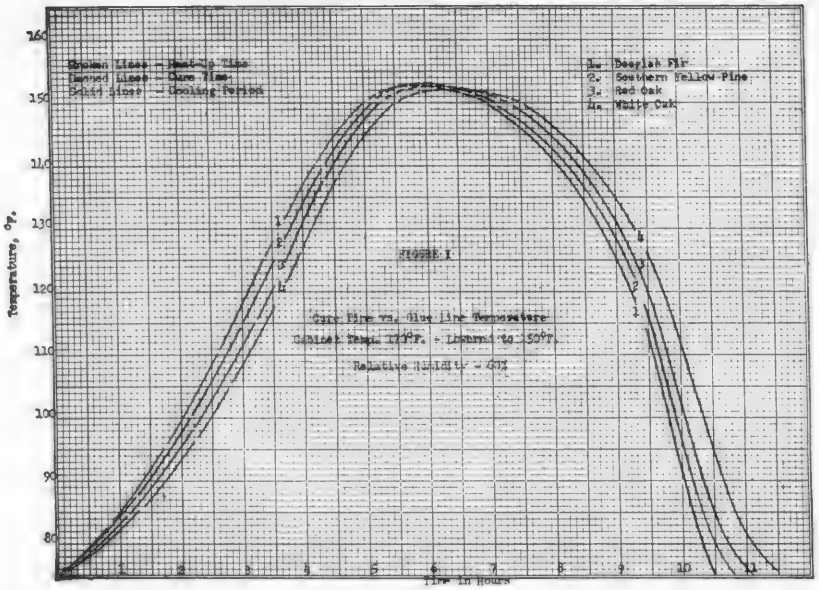
As with untreated wood, a clean surface was required. This was obtained by planing approximately 1/16 in. from each surface to be glued, not less than two hours nor more than six hours before spreading the adhesive. Excessive surfacing was avoided to minimize the removal of preservative concentrated near the surfaces.

Gluing Operation

Gluing procedures employed the recommendations of the following Government Specifications: MIL-A-397A, MIL-W-17445 and MIL-W-15154A. The manufacturer's recommendations for mixing and using were employed. Details are summarized in Appendix.

Spreading was done in a constant temperature and humidity room (52.5 ± 2½ percent relative humidity) where the wood and glue mix were kept at 75° F. before and during the spreading. Each test-beam consisted of a 6-ply laminated assembly 24 in. long. Four rocker-head, two-bolt retaining clamps provided pressure during the curing stage. A torque wrench measured the desired pressure.

The adhesive was cured for two hours at a glue line temperature of 150° F. Heating commenced immediately after clamping. Heat-up time was in the range of four to six hours (Figure 1.) Time of cure was increased to six and ten hours when satisfactory bonding was not obtained after the standard two-hour curing cycle. A maturing period of six days, where the test-beams were held at 75° F. and 52.5 ± 2½ percent relative humidity, preceded the twelve-day cycle test.



Testing

The American Society for Testing Materials' D-1101-50T procedure for 3-cycle (12 days) testing was used in this study. (See Appendix) The maximum lengths of delamination were observed by eye and recorded for each end-grain surface. Results are expressed as a percentage of total length of glue lines on these surfaces. Measurements of less than 10 percent delamination of the total glue line are considered acceptable.

This paper emphasizes the resistance of the gluebond to delamination under no load. The strength of bonded treated woods has been reported in earlier papers. (See appendix)

Results of Tests

The data accruing from this series of tests are presented in tabular form, Tables II and III, for greater ease of interpretation.

Summary and Conclusions

The more important conclusions derived from this study are the following:

1. Commercially treated wood employing nine preservatives and four species can be adequately bonded with the resorcinol or phenol-modified resorcinol adhesives used at intermediate (150° F.) glue line temperature for 2 hours duration.

2. With certain treatments, and certain woods with the treating retentions as tested (acid cupric chromate on white oak and southern yellow pine; ammoniacal copper arsenite on white oak, southern yellow pine and Douglas fir; and chromated copper arsenate on white oak), curing at 150° F. glue line temperature for longer than two hours is necessary for adequate bonding. (See Table III)

3. The resorcinol and phenol-modified resorcinol adhesives which were tested bond preservative and fire retardant treated woods very well. The straight resorcinol adhesives have slightly greater applicability.

4. The bonding of treated woods is not a great deal more difficult than the bonding of untreated woods. In each, close attention to the details of good gluing concepts is necessary.

Appendix

Preservatives and Solution Preparations

1. Grade 1 Creosote

Analysis:
Percent water—0.45 percent
Specific Gravity—1.073=8.94 lb./gal. at 100°F.
Insoluble in benzol—1.35 percent
Coke Residue—2.66 percent
Distillation up to 210°C.— 0.8 percent
Distillation up to 235°C.— 8.6 percent
Distillation up to 270°C.—32.4 percent
Distillation up to 315°C.—56.5 percent
Distillation up to 355°C.—76.1 percent
Residue —23.3 percent
Loss — 0.6 percent

2. 5 Percent Pentachlorophenol Solution

Petroleum Solvent: Sohio 4A Petroleum Oil, Standard Oil Company of Ohio, Cleveland, Ohio
Analysis:

Distillation IBP	405°F.	60	—529
	10% —456	70	—542
20	—472	80	—565
30	—486	90	—594
40	—500	EP	—632
50	—513		

Specific Gravity—30.3 API @ 60°, 7.163 lbs./gal @ 100°
Parafinic, percent Volume—55 percent
Olefinic, percent Volume—20 percent
Aromatic, percent Volume—25 percent
Solution Analysis: 4.95 percent Penta

3. Copper Naphthenate Solution

Petroleum Solvent: Stoddard Solvent
Solution Analysis: 0.97 percent Copper

4. ACC (Acid Cupric Chromate)

50 parts copper sulfate ($CuSO_4.5H_2O$)
47.5 parts sodium dichromate ($Na_2Cr_2O_7.2H_2O$)
1.68 parts chromic acid (CrO_3)

5. Ammoniacal Copper Arsenite*

57.7 parts copper hydroxide ($Cu(OH)_2$)
40.7 parts arsenic trioxide (As_2O_3)
1.6 parts acetic acid (CH_3COOH)

6. Copperized Chromated Zinc Chloride

73 parts zinc chloride ($ZnCl_2$)
20 parts sodium dichromate ($Na_2Cr_2O_7.2H_2O$)
7 parts copper chloride ($CuCl_2.2H_2O$)

7. CZC (Chromated Zinc Chloride)

81.5 parts zinc chloride ($ZnCl_2$)
18.5 parts sodium dichromate ($Na_2Cr_2O_7.2H_2O$)

8. Chromated Copper Arsenate

56 parts sodium dichromate ($Na_2Cr_2O_7.2H_2O$)
33 parts copper sulfate ($CuCO_4.5H_2O$)
11 parts arsenic pentoxide ($As_2O_5.2H_2O$)

9 Tanalith

25 parts sodium fluoride (NaF)
25 parts disodium hydrogen arsenate (Na_2HAsO_4)
37.5 parts sodium chromate (Na_2CrO_4)
12.5 parts dinitrophenol ($C_6H_3(NO_2)_2OH$)

*This is dissolved in a 2.8 percent ammonia (NH solution.

Test For Resistance to Delamination

Standard A.S.T.M. #D-1101-50T and MIL-W-17445 (Ships)

The degree of adhesive cure was determined by subjecting each test specimen to a 12-day cyclic test as described here.

1.1 **Test Specimens:** One end of a test-beam, prepared as specified, shall be trimmed by the removal of a cutting 3 inches long, and the end cutting discarded. Six specimens, each 3 inches long, shall be cut from the trimmed end of the test-beam.

1.2 **Vacuum-Pressure Cycle:** The six specimens specified in 1.1 shall be placed in an autoclave, weighted down under water, and a vacuum of 20 to 25 inches of mercury drawn and held for 2 hours. The vacuum shall then be broken, and a pressure of not less than 75 ± 5 psi shall be applied to the submerged specimens and held for 2 hours. The pressure shall then be released and a vacuum of 20 to 25 inches of mercury shall again be drawn and held for 2 hours while the specimens remain submerged. The vacuum shall be released again and a pressure of not less than 75 ± 5 psi applied to the submerged specimens and held for 2 hours.

1.3 **Drying Period:** After the soaking period, the specimens shall be allowed to dry for 88 hours at a temperature of 80° to 85° F. and 25 to 30 percent relative humidity, in an air stream with a velocity of 200 feet per minute.

1.4 **Duration of Test:** The entire 4-day cycle of testing (vacuum-pressure soaking followed by drying) specified in 1.2 and 1.3 shall be repeated twice, making a test of 12 days' duration.

1.5 **Measurement of Delamination:** Measurement of delamination shall be made on all adhesive lines of both end (cross sectional) surfaces of the six test specimens during the drying period of the third cycle when delamination is at a maximum (usually during

Gluing Procedures

Adhesive "X" Resin—100 parts by weight
Adhesive "X" Hardener— 25 parts by weight

Adhesive "Y" Resin—100 parts by weight
Adhesive "Y" Hardener—20 parts by weight
Test beam size (Surfaced)—5½" × 24" × 4½", 3 laminates
Method of spread—Brush
Spread/M. Sq. Ft. single glue line—60 to 70 lbs.—half to each surface
Assembly period—Assembled immediately—0 minutes open assembly, 45 minutes closed assembly
Pressure—Oak—250 psi, Pine—200 psi, Douglas Fir—150 psi

the fourth day of the period). The per cent delamination of the glue lines shall be calculated by dividing the total length of delamination measured along all adhesive lines (as stated above) by the total length of the adhesive lines.

References

United States Department of Agriculture, Forest Service, Forest Products Laboratory Bulletin R1789, "Summary of Information on Gluing of Treated Woods," 1950, M. L. Selbo.

Journal of Forest Products Research Society, Vol. III, No. 5, p. 35, December 1953, "The Gluing of Preservative-Treated Wood for Severe Service Conditions" J. G. Kuenzel, N. V. Poletika and H. B. McKean.

American Wood-Preservers' Association Proceeding Volume 49, 1953, page 113 "Production of Preservative-treated Laminated Timbers" T. R. Truax, J. Oscar Blew and M. L. Selbo.

Discussion

S. F. Stevens (Eggers Plywood and Veneer Company): Of the Chemicals used, which do you call fire retardent salts?

Mr. Gardner: None of the preservatives listed for treating wood in this project can be considered as fire retardant salts at the retentions shown. Higher retentions of some of these salts, for example, Chromated Zinc Chloride at two to three pounds per cubic foot of wood, will provide fire retardance. At the given retentions, only protection from decay and insects is provided.

Production Gluing of High Strength Joints

FOSTER W. BERRY

The Brunswick-Balke-Collender Co., Muskegon, Mich.

A review of the manufacture of laminated maple parts which confirms the adaptability of modern machines and gluing practices in obtaining high strength glue joints. Experience shows that drying, machining, and gluing under proper controls, yields superior joints consistently while employing high production techniques.

THE MAJORITY of the wood items producted by Brunswick in connection with bowling employ hard maple. I am certain that the majority of those present are familiar with these products and that you are also aware of the extreme abuse these products receive in use.

Hard maple has been classed as one of the most difficult of woods to glue and because of its inherent high shrinkage rate and strength it is capable of generating high joint stresses within itself. The combination of severe usage, difficult gluing, and heavy sections of stock required in the sport of bowling combine to create an exceptional problem in gluing.

Manufacturing in this field, as in all others, is highly competitive. Material usage and labor must be kept at a minimum for this reason and consequently demands high production equipment and efficient techniques.

Gluing is one of the factors in woodworking that can be most troublesome to a manufacturer; seriously affecting the acceptance of his product by the consumer. With highly stressed items gluing is not subject to repair; a defective joint, however minor, showing up after the finishing operations have started reduces the part to scrap, since the risk of sending out a defective item is too great to take a chance.

It was previously mentioned that high production equipment is essential for economic reasons. The most important gluing operation employed in our plant is of the line type and semi-automatic in many respects. The burden for satisfactory gluing is therefore largely dependent on proper functioning of equipment and less on the craftsman's skill.

In reviewing our experience for this paper it is obvious that what has developed by planning and been confirmed in practice is a restatement of the principles of good gluing. Following the sequence of material handling the points to be discussed herein are:

1. Stock drying
2. Stock machining
   a. Edge preparation
   b. Facing
3. Edge and laminate gluing

Before proceeding it is well to explain our approach in establishing methods and maintaining controls. Herein, specifications are established by the engineering department for drying of lumber covering all pertinent details regarding final conditions of stock. There are two objects in so doing, first to achieve the properties desired in ultimate product and, second to satisfy the requirements for good gluing.

Specifications are also written to cover processing of the stock and include the details of glue mixing, spreading, assembly time, press cycles, post-gluing conditioning, and maximum time lapse between machining and gluing. Furthermore, laboratory tests and records are set up on a routine daily basis to test and record lumber moisture content and glue joint quality.

It is impossible to assess a relative importance to details leading to satisfactory gluing, each is essential to success and unsatisfactory results obtain in varying degrees with slipshod methods. Thus a more or less chronological sequence is followed in this discussion.

Stock Drying

Hard maple is dried in forced draft kilns following schedules dictated by the usual kiln samples. Piling follows standards practices for hardwoods, to provide lumber as straight and cup free as possible.

Conditioning at end of drying is such as to give stress-free lumber. Subsequent to cooling, stock is rough dressed and solid piled for equalizing in dry sheds. It is a premise in our gluing that moisture content in the several pieces of stock entering one laminate differ by no more than 2%. We know however,

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that on occasion this is not attained and electric meter tests on stock in process show this up. At such times it is also evident that the percentage of poor joints increases.

Moisture content determinations on stock directly from the kiln show a small range and a distribution between shell and core of sample boards of less than 2%. Normal sampling of kiln runs, even selecting stock from slowest and fastest drying portions of a kiln do not necessarily show the maximum range. Equalizing after drying is commonly recommended for this reason and a standard procedure in our operation call for no less than five days of such equalizing.

Machining

Standard woodworking machinery is used in preparing lumber for gluing, there being no changes in feed rate, or head or arbor speeds. After initial cut-off of rough dressed lumber on stock saws, pieces pass either through the planer line or across a jointer and then through straight line rip saws, the choice being dictated by the cutting width desired.

The first machine on the planer line is a facing planer with second head for the preliminary sizing cut. This machine holds a dominant position in leveling out distorted stock. While this type machine performs very well it does not, nor can it be expected to level pieces distorted beyond the point where a moderately heavy cut does not give a plane surface.

Gluing pressures are adequate to flatten out stock even though not properly leveled by this machine. Nevertheless, with high density stock such as maple extremely high glue joint stresses are created thereby, predisposing the joint to failure. On occasions when heavily distorted stock has not been fully flattened and not detected by workmen, the percentage of faulty joints has increased.

The next machine in the line is a double cabinet surfacer which produces the final thickness with smoothly cut faces. This planer is kept adjusted to its highest precision to avoid common defects of doboff, knife marks and the like.

Stock to narrow for direct use is jointed to give at least one good edge on an automatic return jointer, thence moving to straight line rip saws to cut out defects. These saws were re-worked prior to being used in this operation with chain and race, and arbor bearings replaced where necessary. Further, blade run out required correction on one saw. The need for the best maintenance on these saws cannot be overemphasized since this equipment, must be operated at its best to give consistently good results in gluing.

Saw blades of carbide type are of the minimum diameter and are mounted on the arbor with fullest collar diameter possible. Feed arrangement is set to give a straight cut.

There has been no dissatisfaction in gluing from straight line rip saws and attaining the highest quality joints. Nevertheless, there can be no relaxing from constant scrunity of surface quality and it has been our experience that only the faintest saw mark need show on well operated saws, and there is no evidence of burning, tearing or off-angled stock.

Gluing

Gluing is performed on standard high frequency equipment of glue line heating type. Therefore, we use urea type glues formulated for such an application.

It has been found advisable to hold degree of cure to higher levels than is usually considered necessary. In fact joints tested with chisel immediately from press exhibit an excellent percentage of wood failure. The reasoning behind this is that if joint stresses are present in an area which happens to be below average in cure it will open before residual curing takes place.

An important factor in gluing has been found to be in humidification in this department. While the conditions which exist during operation of the machines are not optimum because of rapid air changes in the department, a pronounced improvement has been noted over an uncorrected atmosphere. When blowers are shut down, humidity control is satisfactory. Prior to humidification, erratic results were noted in joint quality as soon as heating of work area was necessary. As a further point the area concerned had radiant steam-coil heaters early in the operation. These were replaced with unit heaters to reduce affect of radiation on stock and prevent layering of air in the department.

The experience in regard to the benefits for humidification confirms opinions expressed by others attesting to the sensitivity of urea resins to stock moisture content. Despite the fact that the lumber averages over 7% and tests on completed item show the same, it follows that surface drying in the few hours stock is in process brings about enough surface change to be harmful to good gluing. Humidification has been a means of overcoming this problem. Limited experiments with altered glue mixes, wetting agents, and fortified urea type resins have not effected enough improvemnt to indicate that humidification can be discontinued.

In the majority of woodworking it is most commonly found that dressed material remains in stock for a period after machining. It is generally acknowledged that in critical gluing operations, changes on surface of stock, and post-machining distortion are detrimental to gluing. The practice therefore, is to hold machined stock no more than four hours prior to gluing. This has not worked out completely since there have been occasions when small quantities were held over one day. The most common reason for this has been unbalance in stock between various components, but since only a very minor percentage of stock processed has been affected, it is therefore not considered of consequence in our work.

The general principles in stock handling above apply to both edge gluing and face gluing. In gluing operations themselves glue spreads are those normal for ureas, gluing pressures vary between individual presses from 250 to 300 p.s.i. and the gluing cycle from 1½ minutes to 2½ minutes.

Included in the stock handling procedure is a provision for a minimum of twelve hours layover after gluing and prior to machining. The residual heat in the stock, which is practically solid piled, rapidly effects post-press curing, and also allows time for glue squeeze-out to harden.

Quality

The Inspection department, in addition to quality checks on parts in process makes a detailed analysis of degrade on the finished product. Their tally shows the number of defective joints to vary from 0.2% to 0.4%. By most commercial standards these items would also be usable, since under normal use they would have little harmful effect. However, as previously stated, the standards are very strict. The feeling is, nevertheless, that this percentage of rejects is too high and should and can be reduced for these show in the finished item (not apparent in the white) and thus include all material and labor costs. There is a constant effort being made to reduce this percentage.

In analyzing the unsatisfactory joints some can be attributed to faulty machining wherein at some stage a twist or a chip resulted in uneven thickness, an end bite or dip in stock. Others are obviously errors in workmanship where a glue spreader skipped and was not noticed. These nevertheless, represent but a small part of the total of unsatisfactory joints, the majority being traceable to swirls or burls in the grain and occasionally to causes which are unknown. It can be said, moreover, that most of this trouble is encountered in the high

lensity maple. The obvious conclusion s that there are marginal gluing condi- ions which occur in a few items with ailure resulting.

Some consideration has been given to true statistical sampling to determine uality. With the above described expe- ience it can hardly be justified since the cost of the samples would be appreci- ably higher than scrapping the unsatis- factory parts.

To summarize: it has been the expe- rience that proper drying, conditioning, and equalizing of stock, followed by careful machining on planers and straight line rip saws, with gluing on HF presses will consistently give high strength joints.

It is my hope that this review will indicate what can be done in modern plants set up to give high speed, quality production and perhaps prove of assist- ance to someone having gluing prob- lems.

Application of Impreg for Patterns and Die Models[1]

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An investigation has been made on the suitability of impreg for patterns and die models. Approximately five thousand board feet of impreg panels were produced from phenolic-resin-impregnated mahogany veneer. When exposed to various moisture conditions, the die models made from mahogany impreg changed in dimensions only about one-third as much as the die models made from the untreated mahogany lumber. Additional tests made on the impreg panels showed that it is highly resistant to heat, is readily carvable, and can be glued with but slight modification of the present methods used in gluing untreated wood. From this investigation the conclusion was reached that impreg panels made from mahogany veneer are superior to the standard mahogany lumber now used for patterns and die models.

WOOD IS ONE of our few natural products that has been used throughout the history of mankind with almost no modification of its properties. Few materials have as versatile applications and have been as universally accepted as wood. Nevertheless, we know that for certain applications some properties of wood are not desirable, such as the tendency to decay when subjected to high moisture conditions, and the tendency to change dimensions with changes in moisture content.

The impregnation of wood with chemical preservatives greatly increases the resistance of the wood to decay. Even though the preservative treatment of wood is relatively new, having been developed chiefly during the last few generations, this process has been widely accepted by the wood industry.

The impregnation of wood with phenolic resins greatly increases the dimensional stability of the wood. This method of treatment is of more recent development than the preservative treatment of wood. The process of impregnating wood with phenolic resins to reduce moisture absorption and dimensional changes, however, has been described rather extensively in many reports, magazines, and technical journals during the past two decades. The wood industry, nevertheless, has been slow in adopting this process to reduce the dimensional changes of wood. This fact may be due partly to the relatively high costs of the treated wood, which has been produced primarily for rather specialized applications where its desirable properties can be utilized and where the relatively high costs of the wood can be justified.

In order better to discuss new applications for this material, a brief review is given here of the methods of treatment, properties, and current application of resin-impregnated wood.

Wood impregnated with phenolic resin-forming chemicals, followed by drying and curing the resin within the wood structure without the application of pressure, is known as impreg (4, 7, 8, 10, 11). This process is, however, chiefly limited to the treatment of thin sections of wood such as veneer, because of the difficulty encountered in obtaining uniform impregnation and in the subsequent drying of wood in lumber-size dimensions. Of course, laminated panels of any desired thickness can be built up from the treated veneer.

In the manufacture of impreg, the veneer is impregnated by forcing the resin solution into the sheets by the application of pressure or by soaking the veneer in the resin solution until the proper amount of resin is absorbed. The impregnating resin should be a slightly polymerized phenolic resin, i.e., a resin of low molecular weight in which the resin molecules are sufficiently small to penetrate the cell-wall structure. Only resin entering the cell wall reduces the shrinking and swelling; that deposited in the voids is of no value. Many resin manufacturers are now producing impregnating resins suitable for the stabilization of wood. The solids content of the resins made by different manufacturers varies considerably, generally ranging from 35 to 75 percent.

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[1] Presented at the eighth annual meeting of the Forest Products Research Society, Grand Rapids, Mich., May 5, 6, 7, 1954.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

To obtain uniform impregnation throughout the wood without the absorption of too great a quantity of resin, the treating resins are first diluted with water to a solids content of approximately 30 percent. Veneer is impregnated by the application of pressure or by soaking in the resin solution until the weight of the solution absorbed is approximately that of the untreated wood, i. e., approximately 100 percent solution uptake. This will give a resin content of approximately 30 percent based on the weight of the untreated dry wood. The treated veneer is then solid-stacked under nondrying conditions for approximately 1 day to allow time for the resin solution to diffuse into the wood structure before drying and curing. The treated veneer is dried in a commercial veneer roller drier or in an oven or kiln that has circulating air. The drying temperature (less than 200° F.) is kept below the boiling point of water to prevent the solution and the dissolved impregnating agent from being forced to the surface of the wood during the early stage of drying by the steam pressure developed in the wood. Veneer in thicknesses up to one-eighth inch can be dried to a moisture content of from 10 to 15 percent in about 30 minutes in a roller drier. Considerably longer time is required if the veneer is dried in an oven or kiln. The resin in the dried treated veneer is then cured by heating at a high temperature. This is a time-temperature reaction; at 310° F. the curing time is approximately 30 minutes.

The treated and cured but uncompressed impregnated veneer can be glued with many of the same glues and gluing processes now used for gluing of untreated wood. It may, however, be necessary to vary certain gluing conditions, such as the amount of spread, assembly conditions, and curing conditions, somewhat from those used with the same untreated species in order to obtain the desired high-quality bonds of the treated veneers.

This treatment of wood will greatly reduce the moisture absorption, swelling, and shrinking of wood with virtually no sacrifice in paintability or thermal insulating properties, and with no serious effects on its gluability. Much less moisture is absorbed by or passes through impreg than by or through untreated wood. The face checking of impreg under weathering conditions is markedly less than that of untreated veneer.

Except in hardness and compressive strength, which are slightly increased, the mechanical properties (2) are not improved by this treatment. Toughness and impact strength are materially reduced. Decay resistance is greatly increased. This increase appears to be due to the fact that the cell walls of the treated wood cannot take up sufficient moisture readily to support decay. Limited tests of resin-treated specimens exposed to marine-borer attack indicate that impreg may have good resistance to these marine pests. Also because of the reduced equilibrium moisture content of resin-treated wood, the electrical resistivity (13) of the material has been greatly increased.

The acid resistance of impreg is high. Its fire resistance is not markedly greater than that of untreated wood. The resistance to heat, however, is greatly increased by resin impregnation. Impreg heated for 60 minutes at 300° F., and then for 60 minutes at each 25 degree increase in temperature up to 550° F., showed no significant charring or disintegrating of the wood until temperatures of 525° and 550° were reached. Also, impreg was heated at 400° F. for 1 hour and then allowed to cool. This cycle was repeated over 50 times with no apparent disintegration of the wood. Untreated wood will char and disintegrate badly when subjected to these conditions of heating.

Impreg has been used for military purposes, such as housings for electrical control equipment, in which its improved electrical properties were utilized. At present impreg is being produced for the construction of acid tanks, in which advantage is taken of its high acid-resistant property. Industry, however, has been slow to take advantage of the most improved property, dimensional stability, imparted to wood by resin impregnation.

At present, resin-treated wood has been chiefly used in its compressed form. This stable form of compressed resin-treated wood (compreg) (4, 5, 6, 9, 10, 12), which is highly compressed prior to the setting or curing of the resin, is sold under various trade names by the manufacturers of this product. Some of the applications of compreg with which we are familiar are tooling jigs and forming dies, cutlery handles, musical instruments, strain insulators (and other applications in the electrical field where a strength, high-dielectric material is required), electrical transformer parts, spar and connector plates, shuttles and picker sticks in the textile industry, sporting goods, and decorative applications.

Considerable publicity has been given to the products that are currently being made from compreg. Until recently, however, industry has paid little attention to the possible uses of the uncompressed resin-treated wood (impreg), even though the lack of dimensional stability of the untreated wood has been a problem of major importance. In many of these applications the increased cost of impreg over that of untreated wood could be readily justified.

One of these applications is the use of impreg for die models in the automobile industry. Since the beginning of mass production of cars, the body parts have been stamped out by steel dies. In order to make the steel dies, models of the correct size and shape must be first made of wood, and from these wooden models the surfaces are duplicated in steel by keller machines (fig. 1). Since the wooden models determine the shape of the steel dies, it is highly important that these models do not change dimensions appreciably from the time the models are made until the steel dies have been completed and production has started. This period of time may vary from a few months to several years, and with changes in moisture conditions the dimensions of the wood models also change. Changes in dimension in the wood models, unless corrected, would be reflected in the dimensions of the steel dies with the result that the final products (car body parts) would not fit together exactly as designed. Frequently these changes may be of sufficient magnitude to require reworking of the entire surface of the models. Since each step in the engineering and tooling for production of a new model is closely timed, any delay is costly from a time and monetary standpoint. The fact that wood changes in dimensions with changes in moisture content therefore presents a serious problem in the automobile industry, and one that has been faced with difficulty for the last 40 or more years.

Most of the efforts that have been made to eliminate or reduce this difficulty involve attempting to prevent mechanically the entrance and exit of moisture with surface coatings (1, 3) such as paint, varnish, water repellents, and related products. These treatments have proved effective in retarding the rate of moisture changes, and are therefore effective in reducing changes in moisture content and dimensional changes when exposures to high or low moisture conditions are for short periods of time. Since surface coatings only affect the rate of moisture absorption and do not significantly change the amount of moisture that the wood can absorb, this type of treatment is not effective in reducing changes in moisture content or dimensional changes of wood when exposed to long humidity-change cycles such as seasonal changes.

The most effective means of reducing the equilibrium swelling and shrinking of wood that has been found up to the present time is the foregoing process of bonding and fixing active chemicals within the cell-wall structure of

Figure 1.—Keller duplicating machine.

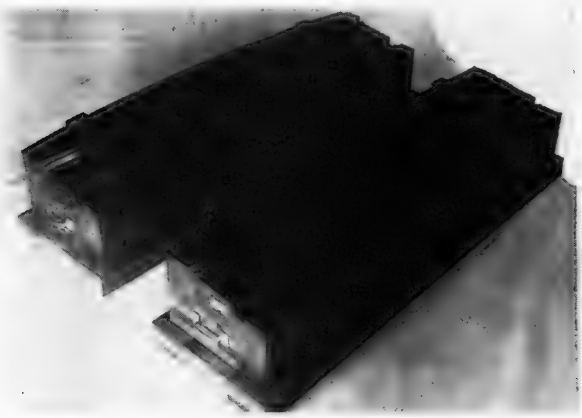


Figure 4.—Die model made from mahogany lumber, left, and one made from resin-impregnated laminated lumber, right.

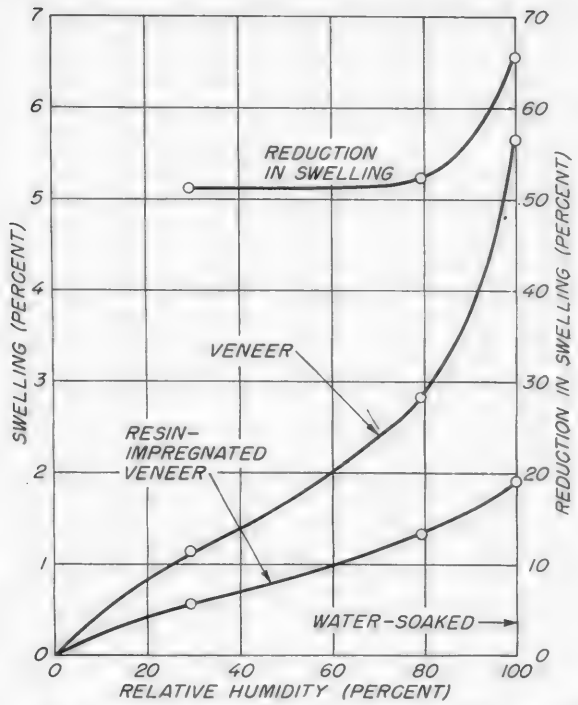


Figure 3.—Effect of resin impregnation on the reduction in swelling of mahogany veneer between ovendry and various moisture conditions.

wood. Phenol-formaldehyde is, to our knowledge, the most effective resin-forming system that is practical to accomplish this objective.

The Ford Motor Company sponsored a research project at the Forest Products Laboratory to determine the suitability of using impreg for making die models and patterns.

The properties of impreg, in general, have been well established. However, the effect of phenolic resins on mahogany for this particular application had yet to be determined. Tests were therefore made to determine the effectiveness of resin impregnation in reducing dimensional changes of the veneer, the laminated panels, and the completed die models. Bakelite resin BR 15100 was used as the impregnating resin for making impreg for these tests. The effect of resin on the gluing and carving properties of this material was also determined.

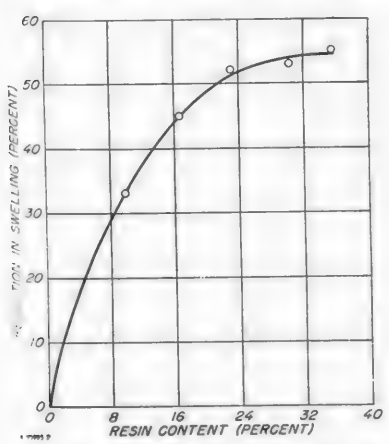


Figure 2.—Effect of resin content on the reduction in swelling of mahogany veneer between ovendry and water-soaked conditions.

The effect of varying amounts of resin on reduction in swelling of mahogany veneer from ovendry to water-soaked conditions is shown in figure 2. The resin content was based on the weight of the untreated ovendry wood. The dimensional stability increased with increase in resin content up to approximately 30 percent, at which point a reduction in swelling of 50 to 55 percent was obtained. Additional amounts of resin do not significantly increase stabilization.

The effect of resin impregnation on the reduction in swelling of mahogany veneer between ovendry and various moisture conditions is shown in figure 3. A reduction in swelling of 50 to 55 percent was obtained when the swelling was determined between ovendry and 30 or 80 percent relative humidity. The reduction was considerably greater, approximately 65 percent, when the swelling was measured between ovendry and water-soaked conditions. The reduction in swelling was still greater when the swelling was determined between 80 percent relative humidity and water-soaked conditions. Under these conditions the percent swelling (as indicated in the graph) was 0.6 for impreg and 2.8 for the untreated veneer. The amount of swelling of the resin-treated veneer is, therefore, only 21.5 percent of that of the untreated veneer. This is a reduction of 78.5 percent. This high degree of stability at the high moisture levels is important when the models come in contact with wet materials such as plaster of Paris in the making of duplicate casts and plastics in the making of duplicate models.

Since the standard die models are built up from mahogany boards, this practice was followed in the fabrication of impreg die models, that is, the treated veneer was first made into boards or panels of comparable thickness and width of mahogany lumber. A conventional hot-press phenol-resin glue was used in the gluing of the veneer into panels. Impreg die models were then built up from these panels by using a room-temperature-setting resorcinol or epoxy resin as the bonding agent.

The first batch of impreg for this application was made at the Forest Products Laboratory. This batch con-

sisted of approximately 200 board feet of laminated panels (approximately 1 x 12 x 48 inches). Each panel was laminated from 17 plies of one-sixteenth inch sliced Honduras mahogany (Swietenia) veneer. Later tests have shown that either well-cut sliced or rotary-cut veneer in thicknesses up to one-tenth inch is suitable for this application.

From this material the first impreg die model (upper back panel) was made by Deutsch and Sons Pattern and Machine Works, Milwaukee, Wis. A comparable model was also made from mahogany lumber (fig. 4). Both models were subjected to 90 percent relative humidity at 80° F. for a month and then to 30 percent relative humidity for the same length of time. The dimensional changes were determined periodically. The comparative dimensional changes of the 2 die models when subjected to 90 percent relative

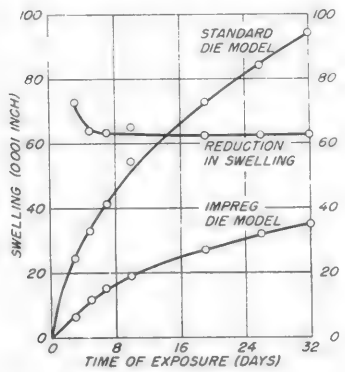


Figure 5.—Comparative dimensional changes of a die model made from mahogany lumber and one made from resin-impregnated laminated lumber. Data represent average of 24 measurements.

humidity are shown in figure 5. Each value represents the average of measurements made at 24 different positions on each model. The results show that a 65 percent reduction in swelling was obtained for the impreg model. Similar values for reduction in shrinkage were obtained when the models were subjected to 30 percent relative humidity.

The irregular surface, resulting from swelling during exposure to 90 percent relative humidity, can be readily observed on the end section of the standard model (fig. 6). This irregular surface (indicated by shadow lines) is the result of differential swelling of the adjacent boards in transverse and longitudinal directions. No surface irregularities are noticed on the impreg model.

Impreg blocks (6 x 6 x 12 inches) were also made from mahogany lumber and from the impreg panels. These blocks were subjected to a moisture condition of 80 percent relative humidity for approximately 3 months. Dimensional changes in the two directions, parallel to, and across the laminates were determined at various distances from the end of the blocks. The results (fig. 7) show approximately 65 percent reduction in swelling for the impreg blocks. The decrease in the amount of swelling for each successive point of measurement from the end of the block indicates that equilibrium swelling throughout the block had not been attained in this period of time.

Figure 6.—End view of die models showing surface irregularity of standard die model (upper) after exposure to 90 percent relative humidity for 1 month. Shadow lines on end of top model are due to differential swelling of the adjacent boards in transverse and longitudinal directions.

The greater degree of stability of the impreg die model and impreg block as compared to that of the treated veneer is at least partly the result of laminated construction that in itself tends to reduce dimensional changes.

The reduction in dimensional changes of phenolic-resin-impregnated wood is not affected by the length of time of exposure to humidity conditions, as the equilibrium moisture content of the wood is permanently reduced by this treatment. This effect is apparent by the fact that the reduction in swelling of impreg blocks over a period of 3 months was the same as that obtained for the impreg model for a period of 30 days. While the stability of die models has not been determined over long periods of time, it is reasonable to assume that the dimensional stability of the impreg models is as permanent as the stability of the impreg veneer and panels from which they are made.

It has been emphasized that impregnants that do not penetrate the cell wall of the wood fibers do not permanently reduce the equilibrium moisture content of the wood. They, therefore, are not effective in materially reducing dimensional changes that occur over long periods of time. There are commercial processes using water repellents and other impregnants together with wood preservatives that are effective in reducing moisture absorption, dimensional changes, and decay of wood in application where shedding of liquid water is a factor. However, at this time we know of no impregnant that is so effective, economical, and practical to use as phenolic resins in an application where a high degree of permanent stability is required.

In the fabrication of models from untreated mahogany lumber, polyvinyl resin glues are currently being used for gluing the boards together. This type of glue depends on the partial loss of moisture to the wood; that is, the partial drying of the glue to give a good initial bond. Such a glue appears to be satisfactory for gluing untreated wood that will absorb moisture from the glue sufficiently rapidly to give a satisfactory bond during the desired pressure period. This type of glue, however, was found to be unsatisfactory for the bonding of impreg panels, since the absorption of water by the treated wood is too slow and incomplete to give a good bond during the period of time that the material is clamped together. It has therefore been necessary to use a glue that does not depend primarily on the absorption of moisture by the wood to give a good glue bond. The various thermosetting resin glues, which harden or cure by undergoing a chemical reaction, naturally suggest themselves for such an application. Such glues, which are capable of reaction at normal room temperatures, are most desirable. Resorcinol resins or epoxy resins that set up at a room temperature of 70° F. or higher have proven satisfactory for this purpose when properly used. Certain other types of glues are under investigation.

Tests on the impreg die model made from the original 200 board feet of mahogany impreg and on the conventional die model made from mahogany lumber showed that impreg is far superior to normal wood for this application. It was therefore desirable to test further the suitability of this material in larger die models. Consequently, 2 roof die models were made, 1 from impreg (fig. 8) and 1 from mahogany lumber. A roof model was chosen because it is one of the largest die models made, and also because experience has shown that it will change

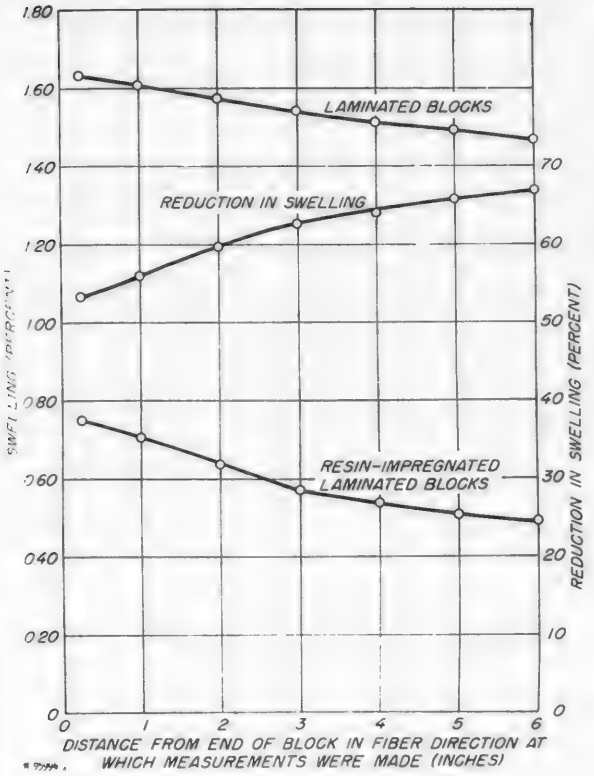

LAMINATED BLOCKS
REDUCTION IN SWELLING
RESIN-IMPREGNATED LAMINATED BLOCKS
REDUCTION IN SWELLING (PERCENT)
DISTANCE FROM END OF BLOCK IN FIBER DIRECTION AT WHICH MEASUREMENTS WERE MADE (INCHES)

Figure 7.—Comparative swelling of resin-treated and untreated laminated blocks (6 x 6 x 12 inches) when exposed to 80 percent relative humidity for 112 days after prior conditioning to equilibrium in 30 percent relative humidity. Data represent average values for radial and tangential measurements.

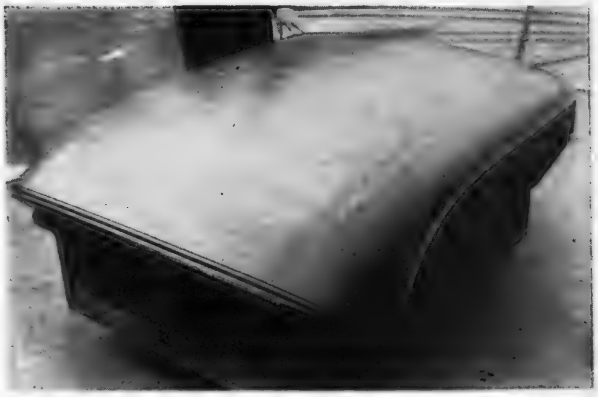


Figure 8.—Roof die model made from mahogany impreg.

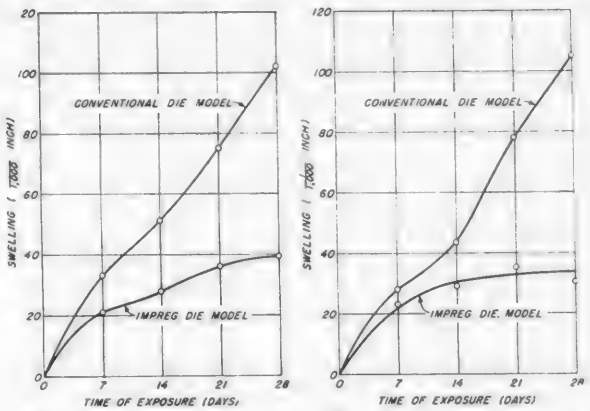


Figure 9.—Comparative dimensional changes in A, width, and B, length, of a roof die model made from mahogany lumber and one made from resin-impregnated laminated lumber when subjected to 90 percent relative humidity.

in dimensions extensively due to moisture changes.

Comparative exposure tests at 90 percent relative humidity and at 80° F. were made at the Forest Products Laboratory on the 2 models. Dimensional changes were determined after each week of exposure for a period of 4 weeks. Comparable dimensional changes in the width and length directions of the 2 models are shown in figure 9. The reduction in swelling of the impreg die model as compared to that of the conventional die model is in close agreement with the results obtained on the smaller die models previously tested (fig. 5).

Comparable sectional views (figs. 10, 11, 12) of a roof panel die model made from conventional mahogany lumber and a similar die model made from impreg taken after the models had been exposed to 90 percent relative humidity for 4 weeks, clearly show the lack of movement in impreg as compared to untreated mahogany lumber.

For the construction of the roof die model and for various other tests, approximately 5,000 board feet of impreg panels were produced by Haskelite Corporation, Grand Rapids, Mich., and by Nickey Brothers, Memphis, Tenn., in cooperation with Koppers Company, Wood Preserving Division, Orrville, Ohio. From this supply of material, each die-model shop and pattern shop in the Chicago, Milwaukee, and Detroit areas that make models for the Ford Motor Company made experimental models from this new material. From their experience, there is no indication that it is any more difficult to make a model from impreg than from conventional mahogany lumber. In fact, there is every indication that it will be easier. Generally, no increased dulling of the tools was experienced while working with this new material, and the surface of the models made from impreg was easier to sand to a smooth finish than the surface of the models made from conventional mahogany.

Several die models for the 1956–model cars have been made from this material. They are now at the various tool and die shops where the hard dies are being kellered from them. It is expected that no difficulty will be experienced. The use of models from this new material will enable the tool manufacturers to take from the die model as many plaster or plastic casts as desired without experiencing any change of dimension or extortion of the original model. Also, from a practical usage standpoint, the model will be dimensionally stable throughout its life.

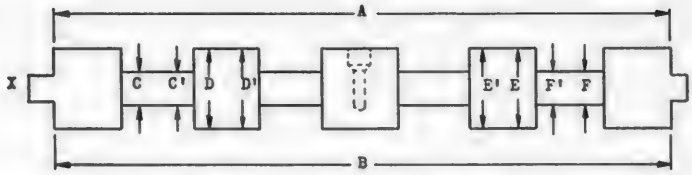
Making die models from this material will also allow the automotive industry the opportunity of using to a greater extent duplicate plastic die models. This is because the original model made from impreg will not change dimensionally due to the application of plastic over it.

The Ford Motor Company has made wood crankshaft patterns from impreg that were used to make experimental shell-molded crankshafts. In this application advantage is taken both of the dimensional stability and heat-resistant properties (figs. 13, 14) of this material, inasmuch as the pattern is heated for an hour to 400° F. before the mixture is set and resin is applied. Because of the heat that the patterns are subjected to, a heat-resistant glue, such as resorcinol glue, must be used for bonding the boards together for this application. The shells obtained are very satisfactory, and the use of impreg in this experimental application appears promising.

Figure 10.—Top center surface of die model made from mahogany lumber (above) and the same surface of one made from impreg (below). The shadow lines on left show raising of the boards due to the swelling and movement of the wood. No raising or distortion of the wood occurred on the model made from impreg.

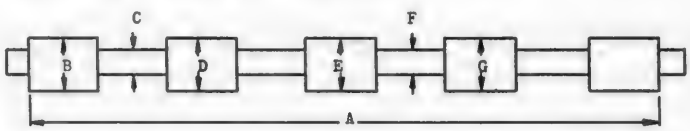
Also, the Ford Motor Company is experimenting with impreg for the construction of other types of wooden patterns.

Since the presentation of this paper, 30,000 board feet of mahogany impreg has been produced by Haskelite Corporation and by Nickey Brothers, Inc., for the Ford Motor Company and manufactured under specifications set up by the Forest Products Laboratory. This material is being used for making pattern and die models for the production of the new-model cars. Plans are being made for ordering additional material from these firms.



	A	B	C	C'	D	D'	E'	E	F'	F	REMARKS
Before Heat	18.472	18.460	1.016	1.014	1.901	1.901	1.905	1.905	1.010	1.012	
300°1/2 hour	18.475	18.468	1.023	1.020	1.902	1.902	1.909	1.907	1.014	1.017	
300°1 hour	18.476	18.467	1.020	1.019	1.899	1.901	1.906	1.905	1.013	1.015	
	.004	.007	.004	.005	.002	--	.001	—	.003	.003	
Before 350°	18.471	18.460	1.013	1.010	1.890	1.889	1.895	1.895	1.005	1.006	
350°1/2 hour	18.478	18.470	1.020	1.018	1.898	1.898	1.903	1.904	1.012	1.015	
350°1 hour	18.479	18.471	1.0185	1.016	1.894	1.894	1.900	1.901	1.010	1.013	
	.008	.011	.0055	.006	.004	.005	.005	.006	.005	.007	
Before 400°	18.472	18.460	1.014	1.010	1.894	1.893	1.898	1.899	1.005	1.007	
400°1/2 hour	18.479	18.467	1.018	1.019	1.898	1.896	1.902	1.902	1.011	1.016	
400°1 hour	18.481	18.466	1.021	1.016	1.895	1.894	1.905	1.906	1.018	1.026	
	.009	.006	.007	.006	.011	.011	.007	.007	.013	.019	
Before 425°	18.467	18.452	1.013	1.008	1.883	1.882	1.899	1.893	1.011	1.018	
425°1/2 hour	18.477	18.466	1.019	1.014	1.896	1.893	1.902	1.905	1.016	1.023	
425°1 hour	18.476	18.463	1.020	1.013	1.895	1.894	1.902	1.903	1.018	1.025	
	.009	.011	.007	.005	.012	.012	.011	.010	.007	.007	
Before 450°	18.466	18.455	1.011	1.006	1.879	1.881	1.890	1.891	1.010	1.016	
450°1/2 hour	18.472	18.463	1.016	1.014	1.893	1.894	1.903	1.904	1.017	1.021	
450°1 hour	18.471	18.459	1.018	1.013	1.887	1.889	1.895	1.897	1.015	1.020	
	.011	.004	.007	.007	.008	.008	.005	.006	.008	.004	
Before 475°	18.456	18.448	1.005	1.001	1.870	1.871	1.878	1.881	1.005	1.011	
475°1/2 hour	18.469	18.458	1.013	1.007	1.887	1.885	1.889	1.892	1.013	1.020	
475°1 hour	18.468	18.456	1.011	1.003	1.879	1.878	1.886	1.887	1.010	1.015	
	.012	.008	.006	.006	.009	.007	.009	.006	.005	.004	
Before 500°	18.455	18.445	1.003	1.000	1.860	1.860	1.873	1.876	1.008	1.013	
500°1/2 hour	18.468	18.456	1.013	1.010	1.876	1.875	1.884	1.884	1.014	1.021	
500°1 hour	18.464	18.455	1.011	1.006	1.874	1.873	1.880	1.880	1.017	1.022	
Before 525°	18.454	18.443	1.000	.998	1.855	1.854	1.863	1.867	1.002	1.005	
525°1/2 hour	18.470	18.457	1.011	1.009	1.871	1.870	1.874	1.879	1.009	1.016	
525°1 hour	18.465	18.450	1.011	1.003	1.867	1.864	1.871	1.873	1.012	1.020	Lamination Separating
Before 550°	18.435	18.420	.998	1997	1.846	1.847	1.846	1.851	.999	1.003	
550°1/2 hour	18.455	18.443	1.012	1.009	1.870	1.866	1.864	1.874	1.019	1.018	
550°1 hour	18.423	18.414	1.016	1.019	1.867	1.867	1.872	1.871	1.025	1.021	

Figure 13.—Dimensional movement of impreg due to heat, showing the results of a test where the impreg was heated for 1 hour at different temperatures. Measurements were taken at the end of ½ hour and at the end of 1 hour.



	A	B	C	D	E	F	G	REMARKS
Before Heat	18.443	1.397	.975	1.889	1.887	.968	1.396	
400°1 hour	18.453	1.895	.980	1.893	1.837	.977	1.332	
Before Heat	18.440	1.885	.975	1.880	1.875	.965	1.870	
400°1 hour	18.447	1.892	.973	1.886	1.879	.968	1.878	
Before Heat	18.438	1.881	.972	1.876	1.863	.962	1.864	
400°1 hour	18.449	1.889	.974	1.836	1.877	.963	1.873	
Before Heat	18.436	1.878	.971	1.871	1.867	.960	1.363	
400°1 hour	18.452	1.890	.973	1.882	1.883	.965	1.893	
Before Heat	18.437	1.875	.963	1.869	1.864	.957	1.362	
400°1 hour	18.447	1.835	.972	1.879	1.376	.966	1.374	
Before Heat	18.431	1.875	.972	1.872	1.867	.960	1.361	
400°1 hour	18.445	1.884	.973	1.879	1.875	.963	1.875	
Before Heat	18.433	1.874	.966	1.867	1.362	.956	1.857	
400°1 hour	18.443	1.884	.973	1.375	1.871	.965	1.370	
Before Heat	18.435	1.872	.964	1.866	1.852	.957	1.857	
400°1 hour	18.443	1.882	.969	1.875	1.870	.961	1.869	
Before Heat	18.436	1.872	.965	1.865	1.861	.955	1.857	
400°1 hour	18.448	1.879	.968	1.872	1.869	.965	1.867	
Before Heat	18.435	1.870	.966	1.865	1.359	.955	1.856	
400°1 hour	18.449	1.878	.969	1.872	1.870	.963	1.865	
Before Heat	18.434	1.869	.963	1.865	1.353	.955	1.353	
400°1 hour	18.448	1.879	.970	1.873	1.363	.961	1.865	

Figure 14.—Dimensional movement of impreg due to heat, showing the results of a test where the impreg mahogany was heated to 400° and allowed to cool 11 times.

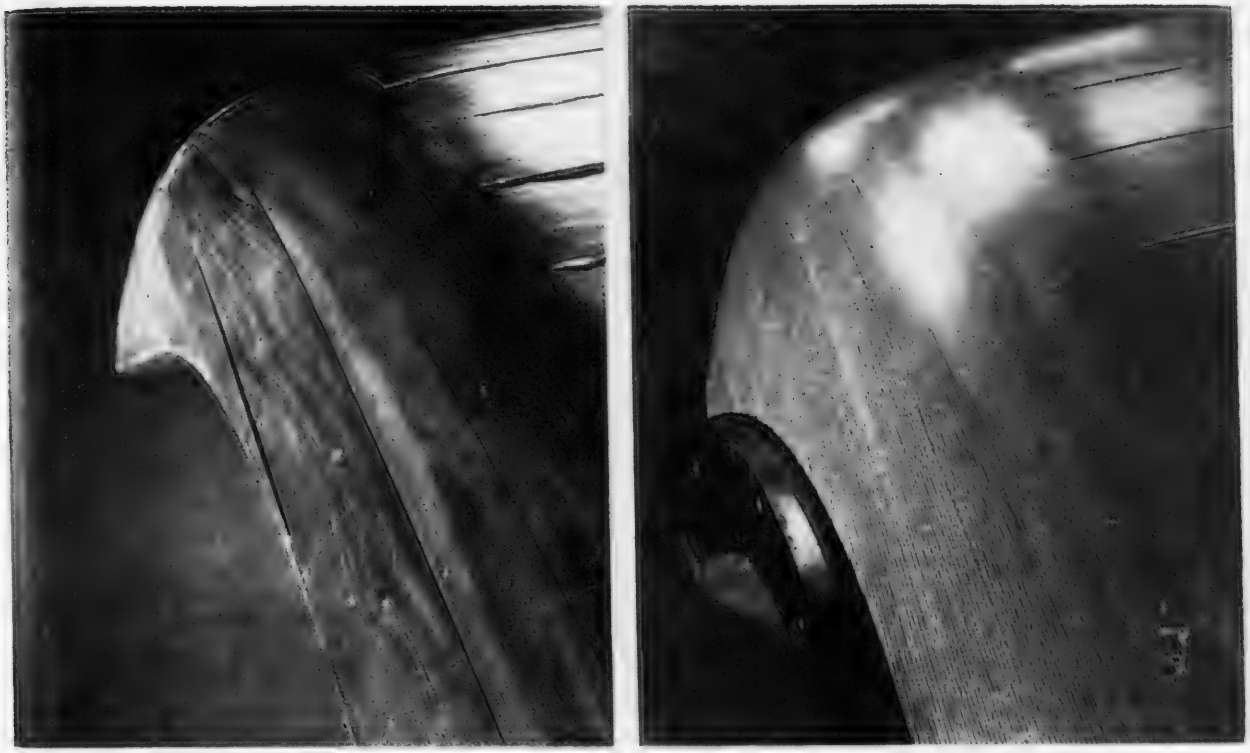


Figure 11.—Surface of rear corner of roof die model made from mahogany lumber (left) and the same surface of one made from impreg (right). The shadow lines on left show raising of the boards due to the swelling and movement of the wood. The upper right corner of the photographs shows the difference in the amount of wax squeezed out of the expansion joints due to the excessive swelling on conventional mahogany.

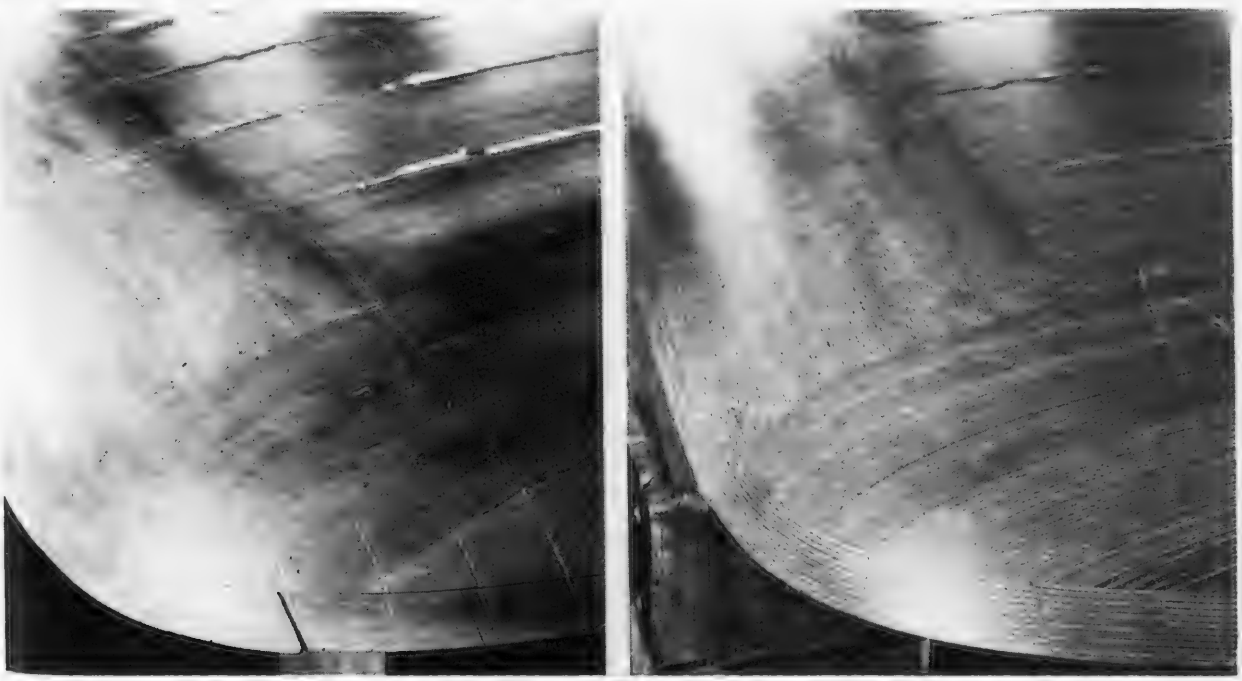


Figure 12.—Surface of front corner of roof die model made from mahogany lumber (left) and the same surface of one made from impreg (right). Notice on photograph left how the offsetting of the scribe lines show the excessive movement of the conventional wood.

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Designing With Glued Wood Construction

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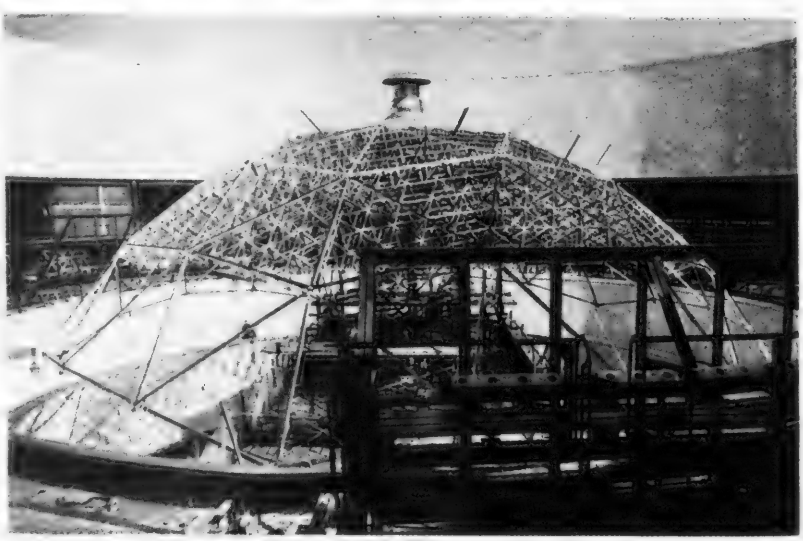
WHEN I WAS ASKED TO SPEAK at this conference I thought that I must be very much of a stranger to your subject because I know so very little about adhesives and I am even a stranger to chemistry. But after some thoughts were expressed to me, I decided that my work was in the neighborhood of adhesives, and that I would therefore be glad to at least tell you of my experiences.

We are conducting experimental structural work at a number of different universities today, and having some success if we measure our experiments in terms of performance per units of invested resource, whether it be weight of material or time. We are making experimental structures which do show such large gains in performance per pound that I would like to talk for a few minutes about the method of conducting those experiments. First, I conduct experiments at architectural schools at various universities. These have invited me to address them in a series of programs starting about 7 years ago. I was very much surprised to be invited and the first thing I had to make clear to architectural students was that we did not build buildings out of materials. What we do is to develop structures of large modular interstices out of structures of very small modular interstices. In other words, nature deals in structures in various magnitudes, and what we are used to calling structures are simply structures in which the modules are too small for us to see. I know that I, myself, grew up with the idea that adhesives are simply a part of chemistry, and for some reason or other things stay together. I am pretty sure that, from listening to some of your speakers, it is still true that many men do not see in terms of structures, but rather do things in terms of behaviors and reliable behavior patterns. I became very much interested a number of years ago in chemical structures as explored by Linus Pauley and in fundamentals of structure as they might most probably be employed by nature. I would like to mention one very important aspect of structures, from the viewpoint of experimental work and possible mathematical principle. There is a word which I find very few people are familiar with and that it is the word "synergy", the combined effective action of every unit of a system. When we consider just a nail or cell of cellulose fiber we cannot necessarily predict a building or paper.

The Fuller Principle

And when I talk about synergy as a scientist, I find that I can best demonstrate it by talking about, for instance, the simplest structure we know about, a tetrahedron, a four-sided pyramid. In a tetrahedron we have six edges which make themselves up into four triangles.

Not until we have these six edges in place do we have a system; and once they are in place the resultant structure



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is almost impregnable, as far as principles go. I began to experiment with a tetrahedron and an octahedron and learned something about their fundamental mathematics. As a result we have been able in the last 7 years of structural experiment, to make such gains in the enclosure of space that we are at the present time enclosing useable volumes in a manner to withstand all the stresses the structure will receive, and doing so with as little as 1/300ths of the weights of materials that men are accustomed to use in such structures. I have developed some new phases of this structure itself which I thought would be most appropriate to present to you today.

In our structural experiments we do not work from drawings as is usual in the automobile business, or in the shipbuilding practice, or in aircraft. We work in the terms of points of controls of systems and in stresses that occur between these points, and we learn how to identify the numbers of points which will be required to give effective service to any structure that is going to be needed for one purpose or another. I tried to discover the number of contacts and the frequency of contacts of various uses of structures. By identifying all those control points we find the shortest ways of connecting them up without interfering with the useable spaces.

Celebrated Ford Dome

Yesterday I flew over the dome we constructed over the Ford Motor Company's plant in Dearborn for their 50th anniversary. There was a 93 foot clear span and the dome that we put in place weighed only 17,000 pounds. This was 1/29th the weight of any dome that could be built by conventional steel radial arch frames, and the reason that I was given the order is that the conventional methods of solving the problem would not do. It went into place in about one fourth the time that it takes to put any other type of dome into place. The Ford Motor Company dome was done with aluminum sheet struts.

Experiments with Paperboard

While we were considering the Ford problem I also had a problem at Yale University when we tried out for the first time the use of paperboard in the making of large structures. When we made the experiments we didn't even try to get a paperboard relatively impervious to moisture, but simply tested out the dry strength of paperboard for structures. We made a 30 foot experimental dome which was installed on top of the architectural building of Yale University for a month and a half. We finally had to remove it because the rains began to soften the materials. We followed this with a research program in which six of the Yale students did their engineering theses work on an investigation of the possibilities of developing paper boards that would be sufficiently impervious to water and moisture to be reliable in performance of these paperboard constructions. The results of their work indicated that it was possible to develop papers which with a phenol resin content of 20%, would be sufficiently stable against moisture, and that if papers of this phenol resin content were used in making a corrugated paperboard, and we used a waterproof adhesive, we might be able to build structures that would be satisfactory without further treatment. However, the problem also required operation of large paper-making machines at $3,000 an hour, as well as the possibility of vast sums for damage that might be done to such machines as a result of experiment. So, I started a series of experiments to give us more information about paperboard structures without having to wait for the paper industry to be familiarized with our problem. We took the corrugated paperboards, made structures out of them, and painted them with poly-ester resins. I saw that it might be possible to use the paperboard as forms for laminates with great economy. I saw too that in the poly-ester resin laminate art there was a viewpoint in tooling which persisted from the forming of metals, which seemed to say that if we wanted to get economy in mass production we must have high speed cycles of forming which could be done only by using withdrawable tools. In poly-ester resin forming we could employ heats and pressures, and could use dies to give us those heats and pressures. I visualized that in cardboard there lay the possibility of making forms which would be so inexpensive that we could leave them right in the construction work, and that this could change the entire concept of production. Not only could we leave cardboard forms inside of laminates, but in doing so I would not be faced with the structural necessity of designing so that tools could be withdrawn. We saw that after we could leave our forming tools of cardboard in the work, we could readily laminate at 360 degrees around the forms, leave the forms in place, and by so doing, increase strengths greatly. The dead weights of the cardboard left in place were negligible and if the cardboards themselves were of the original waterproof construction they had no tendency to take on any additional weight of importance from a dead weight viewpoint. We found that in making structures of poly-ester laminates wrapped around cardboard structures we could not only make a 360 degree enclosure, but could follow through around joints and complex types of joints such as pretzel joints so that we could begin to do what nature herself does in building a tree, starting with a tendril.

Domes as Light as One Pound Per Square Foot

Thinking of the cardboard originally used as a tendril such as nature uses in starting a plant, we found that if we wanted to run out a branch we could wrap more laminates around it because a 360 degree laminate does not require mechanical structural bond to the structure below it but simply has to adhere to itself and complete its own rings. The strength is inherent in the surface rings themselves. In following through on this kind of structure I developed the enclosure used in the Ford dome. Here, space was covered by 2½ lbs. of structure per square foot. The lightest dome in previous history was one built in Great Britain two years before in which they had accomplished coverage of 6 lbs. per square foot of coverage space. The new method of using poly-ester and glass on cardboard began

to give dome enclosures that were very close to 1 lb. per square foot. In the experiments at the different universities we excited the interest of some of the armed services—in particular the Marine Corps. The Marine Corps has a lot of new advance base problems of an entirely new type. They came to me at North Carolina State College, where I had started on one of my projects, and told me of their problem which springs from the fact that due to entirely new technology in aircraft, air strips are no longer needed. Therefore, it is possible to move a base on a moment's notice. The new vulnerability and new success in advance base strategy are going to depend upon the rapidity with which bases can be moved.

Expendable Mass Housing

They also needed advance base housing which can be installed in seconds, and which must be very much more effective housing than the old tentage. The Marine Corps hearing about the work we were doing in very light structures which were now getting into cardboards and poly-esters, presented the problem very frankly as being a critical one. We started further experiments in structures of cardboards and poly-esters. In tests of columns made of cardboard that was poly-ester treated, and glass, we found that we were overbuilding and getting much more strength although the structures were extremely light. It was discovered that a cardboard column just painted with poly-ester gave us similar strength. For example, taking a light paperboard, about 90 lbs. per thousand square foot corrugated board, and making a column in which the corrugations were 90 degrees to the axis of the column, and using a very light paper liner, such a column with a 4 inch edge to the triangle, in section and 3 ft. high weighed only about one-fourth pound and in the press just as paperboard, would accordion and collapse when the press got up to 25 lbs. This same construction when painted with poly-ester with an average thickness of less than 1/64th of an inch went up to 580 lbs. This was without the glass. We found that the poly-ester was being reinforced by the little fibers of the kraft paper itself and that this thin reinforced egg-shell form of construction was giving us phenomenal strengths. So we began to explore further with such structures. As a result, at the present moment we are building at Cornell a 36 foot dome for the Marine Corps which gives a thousand square feet of cover. It is being covered with a poly-ester coated water-proof card boards of the V-series. The components of this dome are diamond shaped structures about 6 feet on an edge of the diamond by about 9 feet along the longest axis. They look something like an oak leaf. They have a long convex curvature toward the center of the building on the long axis, and a concave curvature on the short axis. We bostitched the units together and the 36 foot structure covering 1,000 square feet, weighing 400 pounds, will be down to 4/10 of a pound per square foot of covered surface, and will carry the full snow loads.

Work with Universities

We are carrying on this same principle of work at a great many universities this year; at Princeton, the University of Minnesota, Tulane, University of Virginia, Virginia Polytechnic Institute, and the Massachusetts Institute of Technology. At all of these universities the students are learning to work directly with the new resins instead of the designers working-up dream ideas on paper and then wondering what contractor can possibly carry out such work. These students are actually making the structures themselves. I can tell you that from the viewpoint of adhesives we have a number of important new problems. At all of these schools we are face to face with very desirable new adventures, as for instance, what we could do with Mylar, a little known Dupont material. We made a 36-foot dome with Mylar and waterproofed plywoods at the University of Oregon last year, in which 40 students, in eight days, working in three shifts around the clock, produced a finished structure. However, when we came to the adhesion of the Mylar to the wood we were up against it. Being very stable Mylar was extremely desirable. Here was a thin film which could enclose large structures effectively and transparently and with great economy and speed if we only knew how to adhere it.

Adhesive Problems

Last summer we had an opportunity to build a large dome at Wood Hole, Massachusetts, and it also was to be covered with Mylar. We obtained a 3 mill Mylar from Dupont and started experiments. We tried out all adhesives recommended by Dupont. We had also tried them out on the Mylar enclosed growth house for North Carolina State Agricultural School where we had very poor success. However, at Concord we finally did find an adhesive which would seem from Mylar to Mylar and from Mylar to wood to be effective. We installed a large diamond panel, 11 ft. on an edge, therefore about 19 feet on its long axis. It was made up of panels of Mylar adhered and overlapped about 3 inches. That was in October, and it went through snow loads and enormous storms that winter. It was installed on a high panel of the structure where the gales would come under it and over it, and this spring it was completely nonfluttering. At this time it still is not fluttering, and still can be walked on. A man can stand in the middle of it so we have decided the adhesive was pretty good. However, we found at other schools, we couldn't duplicate the experimental work we have done at Concord.

In the case of the Cornell dome we are for the moment just stitching the edges of the diamonds. We are going to overlap panels. We are bostitching them together temporarily for the purposes of the Marine Corps and running tape on the joints. However, the Marine Corps in looking at this latest run have agreed that it is so relatively inexpensive that probably it would pay to throw in adhesives and when through with it, just leave it. We found that if we can make thousand foot domes that weigh only 1400 lbs. each we can assemble them in preferred places and fly them to other places with helicopters. At the end of last January we did start flying domes with helicopters from behind the lines to the advance bases. That was a 1400 lb. dome and you can imagine how effective the 400 lb. dome will be that we are doing at Cornell. Two weeks ago at the University of Michigan, we had a one-week problem at the architectural school where we made a 14-foot diameter three-quarter sphere, 10 feet high, out of poly-estered cardboard. It was very rapidly made of triangular facets that weighed only 60 lbs. We were able to take the structure apart in two minutes, but if we had put in adhesives, of course, we would have had to crush it or find some way of disposing of it. We don't think it pays to separate adhesives in such structures, and you either make them with adhesives in such structures, and plan to fly them from one place to another, or else leave them behind.

I hope that my very informal way of dealing with this problem will encourage you in your work. I am convinced that new knowledge is going to lead to entirely new ways of enclosing space, that it is very intimate to the advance strategy, and will in due course, be of some importance to our civilian population. It is interesting what could be done in terms of great emergencies, in the enclosure of space by the relatively stable polyester on paperboard domes, or by the new paperboard domes that we can make without doing any polyestering at all. We believe it possible to turn out as many as a million 36 foot domes in one day, thus giving you an entirely new concept of the relationship of man to space enclosure from anything that we have known before

Liability of Manufacturers in Forest Products Industries For Harm Done by the Product

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Historical background leading to courts holding the manufacturer increasingly responsible for injury done to ultimate user is explained. It would appear this trend will continue and that the manufacturer should obtain protection in this area.

I. Introduction

LITIGATION IN WHICH manufacturers of forest products are defendants because of injuries by users of those products is increasing daily. The discussion of liability for such injuries in legal and insurance circles is so prominent that it is proper to review the legal position of the manufacturers of these "chattels" as it has changed slowly over the past several decades and swiftly over the past few years, as well as to try to predict what is likely to develop in that legal position in the near future. And, as a part of this review, we shall see what steps can be taken to guard against the hazards which have been created.

This review will be confined to the manufacturers' liability to users of their products other than their immediate vendees. Liability of suppliers who are not manufacturers has been discussed elsewhere at some length (1).

II. Basis of Liability

A. Historical Background: The law which deals with liability for these injuries is in an interesting state of development with most of this development leading to greater accountability by producers and sellers to the users. "In the case of the sale of chattels, both the English and American law have broken almost entirely away from the ancient rule of *caveat emptor,* that the buyer must make his own inspection, rely upon his own judgment and assume the risks of any defects in what he buys, which still is applied to the sales of real property (2)." Our social philosophy has changed over the years from an attitude of shielding the manufacturer and seller from responding in damages to persons whom they did not know and who might be hundreds of miles away from the factory or the store. Enterprise liability (3) is now generally recognized to be based upon the principle that a manufacturer or dealer has a responsibility to the ultimate consumer, "based upon nothing more than the sufficient fact that he has so dealt with the goods that they are likely to come into the hands of another, and to do harm if they are defective (4)."

Mr. Justice Jackson dissenting in a recent Supreme Court decision concerning the Texas City disaster litigation demonstrated the necessity for this greater accountability in his vivid way (5):

". . . this is a day of synthetic living, when to an ever-increasing extent our population is dependent upon mass producers for its food and drink, its cures and complexions, its apparel and gadgets. These are no longer natural or simple products but complex ones whose composition and qualities are often secret. Such a dependent society must exact greater care than in more simple days and must require from manufacturers or producers increased integrity and caution as the only protection of its safety and well-being . . ."

When one gives the matter some thought it does become apparent that there are opportunities enough in the manufacture of furniture, bedding equipment and appliances, or in fork lifts, scaffolds and stepladders to create defects which can lead to bodily harm. A spring may fly from a divan and strike someone in the eye; a bed slat may break, sending a pregnant woman to the floor with a crash; the catch on a garden chair may snap quickly, cutting off a finger of the unlucky operator; a rung on a stepladder may fracture, causing the window-washer to fall to the ground several feet below with not a little damage to his sacroiliac; the panel raiser head on a shaper may disintegrate, permitting the hand of the operator to be badly cut. Our mores will determine who should bear the burdens of the losses caused by these injuries. The task of the law is to shape theories and thus the procedures by which these objectives are translated into social action. "The life of the law," said Mr. Justice Holmes, "has not been logic; it has been experience (6)."

In any event, in the early years of the Nineteenth Century there seems to have obtained a body of judicial opinion in England and the United States which held to the belief that industrial and commercial progress would be stifled if the entrepreneurs were saddled with too heavy liabilities for the injuries caused by the things which they produced. The law, therefore, developed restrictions against plaintiffs who were injured by such products if these plaintiffs were too remotely related to the manufacturer (7).

This opinion is well illustrated, indeed formulated, by a famous English decision in the year 1842. A gentleman by the name of Wright made a contract with the Postmaster-General of England to supply mail coaches and keep them fit. Winterbottom was a coach driver for a firm which had a contract with the Postmaster-General to deliver the mail in these coaches. One fall day in 1840 Winterbottom was thrown from his coach when it gave way and he was rather badly hurt (9). He thereupon sued Wright, the supplier of the coach.

Now, observe that Winterbottom, the driver, was no party to a contract with the defendant-supplier to keep his coach in good repair. The court found this a fatal defect in the plaintiff's pleading. The judges could not find any duty of care which the supplier owed to this man. And if there was no duty, there

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could have been no breach of duty for which the plaintiff could recover for his aches and pains, doctor's bills and loss of future earnings. In the course of his opinion Lord Abinger declared that

> "There is no privity of contract between these parties; and if the plaintiff can sue, every passenger, or even any person passing along the road, who was injured by the upsetting of the coach, might bring a similar action. Unless we confine the operation of such contracts as this to the parties who entered into them, the most absurd and outrageous consequences, to which I can see no limit, would ensue (10)."

And Baron Alderson seconded this with his own remarks, adding them, as has been wryly said, "in terrorem" (11):

> "If we were to hold that the plaintiff could sue in such a case, there is no point at which such actions would stop. The only safe rule is to confine the right to recover to those who enter into the contract: if we go one step beyond that, there is no reason why we should not go fifty."

This decision, then, appears to have gone further than to hold that no action against the coachmaker could be maintained on his contract with the Postmaster-General; but it has been universally misinterpreted, and certain dicta of the judges were taken to mean that there could be no action even in tort and even if the chattel had been in a defective condition when it was supplied. Springing from this decision, there developed a general rule which has prevailed until quite recent years, that the original seller of goods was not liable for damages caused by their defects to anyone except his immediate buyer.

Thus, the early law barred a person who was injured by a manufacturer's product which he had not purchased from the manufacturer himself first, in contract (because there was no contract between the user and the manufacturer) and, second, in tort (because the manufacturer owed no duty to the user who was not an immediate vendee, that is, was not a party to a contract of sale with the manufacturer).

But this rule was a harsh one, and as our economy has become more complex it has become necessary to shift the damages suffered from the backs of the injured and spread them a little more equitably among those who were responsible for the injuries, namely, the producers. How this has been happening is really the point of this narrative, for it demonstrates the rather rapid shifting of this burden in recent years, and the need for all producers to guard themselves against the risks of enterprise liability.

If a user of the manufacturer's product is to recover from him for injuries he has suffered by the use of that product he must convince the court that the producer has broken a duty owed to the user arising either out of a contract, or arising from an obligation to use care imposed by law. The breach of duty imposed by law, that is, not arising out of any contract is defined as "negligence," and we shall take up the development of ability in negligence first.

B. Negligence Liability: Negligence is not an act itself, but is a fact which defines the character of an act and makes it a legal wrong. It is the breaching of a duty of care which is owed to another causing him injury whereby he is damaged. There must be a duty, a breaking of the duty, the breaking must be done by the manufacturer, and there must be damage to the object of the duty-breach. If any of these elements are missing the plaintiff may be out of court, for he will not have made out the elements of a prima facie case, that is, a case which judging by the plaintiff's allegations only and nothing more in the way of proof from plaintiff or defendant would entitle the plaintiff to recover.

1. Duty: Whether a manufacturer will be liable to an injured user of his product in tort for negligence will depend, as we have seen, upon whether there has been imposed a duty not to injure *that* user. *Winterbottom v. Wright* (12) held that the producer had no duty to a user not a party to a contract with him. To put it another way, the contractor's duty of care was limited to the parties to the contract. The limits of the liability for negligence and for breaches of contract in cases of this character were held to be identical (13). The result of all this was that third parties who without any fault of their own were injured by the negligence of the manufacturer while using his products innocently for the purpose for which they were made could not recover because the manufacturer owed no duty to them as strangers.

As we have noted, this rule became quite fixed in our law, so much so, that the courts rather than upset the rule engrafted exceptions to it, in order to mitigate the harshness of its operations (14):

a. An act of negligence of a manufacturer which is imminently dangerous to the life or health of mankind, and which is committed in the preparation or sale of an article intended to preserve, destroy, or affect human life is actionable by third parties who suffer from the negligence. The most famous case establishing this exception is *Thomas v. Winchester* (15), where a dealer in drugs sold to a druggist a jar of belladonna, a deadly poison, and labeled it "Extract of Dandelion." The druggist used this to fill a prescription for extract of dandelion prepared by a physician for his patient. The unlucky patient took the prescription thus filled, but she did recover from the wholesale dealer for the injuries she sustained.

b. An owner's act of negligence which causes injury to one who is invited by him to use his defective appliance upon the owner's premises may form the basis for an action against the owner. So, in *Coughtry v. Globe Woolen Company* (16) the owner of a building employed Osborn & Martin to construct a cornice, and agreed with them to furnish a scaffold upon which their men could perform the work. He furnished the scaffold, and one of the employees of the contractors was injured by the negligence of the owner in constructing the scaffold. The court held that the act of the owner was an implied invitation to the employees of Osborn & Martin to use the scaffold, and imposed upon him a liability for negligence in its erection.

c. One who sells or delivers an article which he knows to be imminently dangerous to life or limb of another without notice of its qualities is liable to any person who suffers an injury therefrom which might have been reasonably anticipated, whether there were any contractual relations between the parties or not (17). Where the plaintiff alleged that the defendant-manufacturer had knowingly faultily made a cover for the cylinder of a threshing machine which would not sustain the weight of an operator's body, although it was clearly necessary that the operator would have to walk on it the court allowed recovery (18).

On the other hand, where the court does not find the product to be imminently or inherently dangerous it may fail to find that the manufacturer has a responsibility to a user to whom he has not sold the article because he is outside the third exception here mentioned. Thus, in *Field v. Empire Case Goods Co.,* (19) the plaintiff sued the defendant, a manufacturer of household furniture who had made a "circassian walnut bed," which had been sold to the plaintiff by R. H. Macy and Company. The plaintiff alleged that about a year after she had purchased it, "while she was properly and carefully in said bed while in her home in a pregnant condition and about to be delivered of a child, the strips of wood fastened or attached on the inner sides of the bed, upon which the slats rested, suddenly broke and gave way, precipitating plaintiff to the floor, by reason

of which, and caused thereby, she suffered the injuries for which she seeks to recover."

In denying recovery the Court would not recognize that a bed could be an engine of harm.

". . . It is clear therefore that an action cannot be maintained on the facts alleged in the complaint, which do not remove the case from a general rule that an action for negligence cannot be maintained by third persons against the manufacturer of an article not in and of itself imminently and inherently dangerous. An ordinary bed is not an article that is reasonably certain to place life and limb in peril when negligently constructed, or which of itself, in the use to which it is intended to be put, gives any warning of dangerous consequences attending to its use, and the manufacturer is not charged with knowledge of danger in its contemplated use, 'not merely possible but probable'. . . .

"An ordinary wooden bed is such a common article and in such universal use, its manner of construction and method of use having remained the same for generations, that we may take judicial notice of its construction, especially when aided by the allegations of the sixth and seven subdivisions of the complaint, and of the fact that the strips of wood on the inner sides of the side-pieces which form a support for slats were laid crosswise, but a short distance from the floor, sometimes give way. The drop to the floor, however, is so slight, the body of the occupant usually so well surrounded by protecting bedding, that bodily injuries cannot reasonably be expected to result therefrom. Such a bed is not inherently or immediately dangerous to life or limb, and it is shown in the case at bar by the fact that this bed had been in use for nearly a year preceding the accident, without indication of weakness or defective construction. . . ."

These exceptions nevertheless have proved to be fruitful methods of widening the breach in the "manufacturers' citadel of privity" (20) in negligence cases. Let us see how this has happened, beginning with the famous opinion of Judge Cardozo in *MacPherson v. Buick Motor Company*, (21) a case in which the manufacturer sold a car to a retail dealer who in turn sold it to the plaintiff. Because of defective wooden spokes in the wheel the car collapsed while plaintiff was in it, injuring him. Apparently the manufacturer of the car who had purchased the wheels from a manufacturer of wheels could have discovered the defect by inspection, but the defendant failed to make such inspection. In holding that the car manufacturer was liable the New York Court of Appeals, through Mr. Justice Cardozo, held that the principle of liability established in *Thomas v. Winchester* was not limited to poisons, explosives and things of like nature, that is, to things which in their *normal* operation are implements of destruction:

"If the nature of a thing is such that it is reasonably certain to place life and limb in peril when negligently made, it is then a thing of danger. Its nature gives warning of the consequences to be expected. If to the element of danger there is added knowledge that the thing will be used by persons other than the purchaser, and used without new tests, then, irrespective of contract, the manufacturer of this thing of danger is under a duty to make it carefully. That is as far as we are required to go for a decision of this case. There must be knowledge of a danger, not merely possible but probable. It is possible to use almost anything in a way that will make it dangerous if defective. That is not enough to charge the manufacturer with a duty independent of his contract. Whether a given thing is dangerous may be sometimes a question for the jury. There must also be knowledge that in the usual course of events, the danger will be shared by others than the buyer. Such knowledge may often be inferred from the nature of the transaction but it is possible that even knowledge of the danger and of the use will not always be enough. The proximity or remoteness of the relation is a factor to be considered. We are dealing now with the liability of the manufacturer of the finished product who put it on the market to be used without inspection by his customers. If he is negligent where danger is to be foreseen, a liability will follow. . . . In such circumstances, the presence of a known danger, attendant upon a known use, makes vigilance a duty. We have put aside the notion that the duty to safeguard life and limb, when the consequences of negligence may be foreseen, grows out of contract and nothing else. We have put the source of the obligation where it ought to be. We have put its source in the law."

By this extension of the exceptions in this way, the courts have arrived at the position that the mere *probability of harm* better describes limitations on the ability of the manufacturer to escape liability where his products cause injury to the user, "and today the manufacturer's duty of care with respect to his products extends just about as far as the prudent eye can foresee unreasonable harm (22)."

Applying these principles the Supreme Court of California has held that it was a question of fact for the jury to determine whether or not an extension ladder of recent manufacture, when used as the plaintiff was using it became an instrument imminently dangerous to human life or limb (23). Plaintiff had been standing on the top rung of the ladder hanging window screens when the rung collapsed, and conflicting testimony was introduced as to whether the ladder manufacturer inspected the stock used and whether, if he did not, there was any obligation to do so.

2. Breach of Duty: As we have seen, there can be no legal liability and a cause of action cannot exist in the absence of a corresponding duty owing by the party sought to be held by the party injured. We have seen that the scope of this "duty" is ever widening.

Now it is readily apparent that no injury can arise unless the legal duty, whatever it is, has been breached by the manufacturer. Without such a breach, there can be no actionable negligence. The plaintiff must show that his injury is traceable to specific conduct of the manufacturer which falls below the legal minimum standard of care. And proving of the breach of duty is part of the case which the plaintiff must make. This is, of course, not always an easy task to perform, involving as it may, a good deal of engineering and other expert testimony, but it can be and has been successfully done (24).

Usually there is evidence tending to show that the injury caused by a defect is traceable to the defendant and sometimes there is evidence that the defendant's general program of care is inadequate (25).

Of course, the plaintiff must also show that it was the act or failure to act of the defendant-manufacturer which caused the injury to him. Thus if he shows that he stepped on a rung of a ladder which collapsed, it is clear that, unless he had no business there, it is the manufacturer's act of assembling a defective rung into the ladder which led to his injury. However, we do not find the issue of "causation," as it is called, too frequently litigated. It is usually unquestioned and unquestionable that the defective rung in the ladder caused the fall or that the mouse in the soft drink bottle led to shock and illness.

Therefore, as a matter of reading the decided cases, it appears that plaintiffs need usually show only that the injury was caused by the manufacturer's product in order to get the court to find

there is a cause of action, thus leaving the jury to determine whether the manufacturer's actions were such as could be characterized as "negligent" (26). Remember that without characterizing the manufacturer's actions as "negligent" the injured plaintiff will not have any recovery.

Since the injured plaintiff seldom has any direct proof of what has occurred in the manufacturer's plant, he usually must resort to circumstantial evidence of negligence. However, some courts will help the plaintiff over this hardship of proof of negligence by not only letting the case go to the jury by a mere showing of causation, but also by recognizing a presumption of negligence in the plaintiff's favor without, however, shifting the burden of proof. Others go even further in helping the plaintiff by giving him the benefit of a presumption of negligence of the defendant, thus compelling the defendant to prove that he was *not* negligent (27).

a. The defendant may rebut the plaintiff's evidence of negligence by showing that the defect was one which could not have been discovered or avoided by the exercise of all reasonable care. The prevailing view, however, is that mere testimony that proper methods have been used does not necessarily destroy the inference to be drawn from the presence of something inconsistent with reasonable care, and the question of negligence is one for the jury.

b. Another means of rebutting the evidence of negligence by the defendant is to introduce evidence showing the care the defendant uses in making the product. This evidence is, theoretically, of two kinds: the first relates to the specific article causing the plaintiff's injury. Unfortunately for him, the defendant is almost never able to give an account of what happened in the particular case. Like the plaintiff, he must fall back on circumstantial evidence. The second kind relates to the general program of precautions taken with respect to the product to guard against the kind of injury suffered by the plaintiff. Here the defendant elaborately describes his methods of manufacture (including technological devices for intercepting defects), his inspection programs, and his housekeeping methods. Evidence such as this may be used, inferentially, to show (1) that the defect could not have occurred at the defendant's plant, or (2) that, even if it did, there was no negligence.

However, as the issue is not what happened generally at the manufacturer's plant, but rather what happened in this instance, it is not surprising that the plaintiff's chances of recovery are quite good when he shows causation.

3. Damages: The defendant's breach of duty must result in injury to the plaintiff in order to sustain a recovery against the defendant. But once plaintiff has shown the injury the damages awarded can be quite high, and when the defendant is a fairly well known corporation the jury will tend to be even more sympathetic to the plaintiff than otherwise. And where damages may be "the amount which will compensate for all the detriment proximately caused thereby, whether it could have been anticipated or not," (28) it is easy to realize they may be very expensive. For example, in *Phillips v. Ogle Aluminum Furniture, Inc.*, (29) the jury returned a verdict in favor of plaintiff of $25,000. She was injured by falling from a chrome dinette chair. The husband who lost the services of his wife as a result of her injuries was awarded $3,500 for "loss of consortium." Other decisions have also resulted in substantial verdicts (30).

4. Defenses: Of course, when the plaintiff bases his cause of action on the manufacturer's negligence the manufacturer may be able to show that plaintiff contributed to his own injury by his own negligence. In most states this defense of "contributory negligence" is enough to take the defendant out from under any liability at all. An illustration may be found in the furniture manufacturing industry, again, in an interesting bit of litigation in California (31).

Plaintiff and her husband bought an aluminum "S" type chair from a furniture dealer. It had been purchased K.D. by a dealer and assembled by him. The plaintiff stood on this chair to place a sugar bowl in the cupboard above her refrigerator. When she placed her hand on the back of the chair to get down, the back fell off and caused her to fall on one of the uprights, which went into her body, causing her serious injuries. The evidence tended to show that the dealer had used slightly shorter screws in assembling the plywood back to the frame than those the manufacturer claimed he had sent along to the dealer. On appeal from a sizable verdict (32) in favor of the plaintiff and her husband, the defendant store declared that the acts of the store were not the cause of the injuries. It argued that there was no evidence that the chair was not perfectly safe for the sole purpose for which it was constructed, that is, for sitting on, and that it was not designed to be used as a substitute for a stepladder. But the court declared:

> "Although the ordinary use of a chair is to sit on it, it cannot be said, as a matter of law, that it could not be reasonably anticipated that the described chairs would be used for the purpose of standing upon them. This question, as well as the question of whether the negligence of appellant was a proximate cause of plaintiff's injuries were factual questions for the jury to determine, and it did so under instructions fully covering those issues. . . .
>
> "We will next discuss the contention that standing on a chair of this design was contributory negligence as a matter of law on the part of respondents. Appellant argues that ordinarily the question of contributory negligence is one largely of fact for the jury, but in the instant case the conduct of the respondents was so plainly negligent that the question became one of law. . . . It appears from the evidence that no particular inspection by respondents short of taking the chair apart would have divulged that the back was attached by short or inadequate screws. We conclude that the question whether Mrs. Phillips was negligent in standing upon this particular chair, under the circumstances, and whether such negligence, if any, contributed proximately to the cause of her injuries, was a factual question for the jury to determine."

C. Liability on Warranty: Except in the case of food and drugs (33), the law ordinarily requires that there be privity of contract in order for the action of breach of warranty to be maintained by the plaintiff. In effect, the plaintiff is saying that he has relied on representations, express or implied by the manufacturer, of quality or qualities, that these representations were false, and that the plaintiff was hurt by relying on them.

Where the representations are "express" they have articulately been set forth or announced in one way or another (such as by advertising in newspapers). Warranties, which are "implied" are representations which are placed on the seller by law, regardless of any failure to make any express representations by the seller.

Under the Uniform Sales Act (34) "(1) where the buyer expressly or by implication, makes known to the seller the particular purpose for which the goods are required, and it appears that the buyer relies on the seller's skill or judgment (whether he be the grower or manufacturer or not) there is an implied warranty that the goods shall be reasonably fit for such purpose.

"(2) Where the goods are bought by description from a seller who deals in goods of that description, (whether he be the grower or manufacturer or not) there is an implied warranty that the goods shall be of merchantable quality."

However, plaintiffs have not been too successful as against manufacturers in this kind of litigation, although in one or two cases recovery has been allowed against automobile manufacturers by plaintiffs who had relied on special advertising claims of the manufacturers when they bought their cars (35).

The trouble, as far as a plaintiff suing a manufacturer in a forest products case is concerned, is that no representations have been made to *him* by the manufacturer. If he wants to sue for a breach of warranty, he will find that the warranty, if any, does not run to him, at all. So where the *wife* of the purchaser of a bed from a *dealer* suffered a miscarriage because a bed rail broke, she was denied recovery (36). There was no reason for altering the requirement of privity:

> ". . . A bed, such as that described in the petition is obviously not an article that in and of itself is imminently or inherently dangerous to the users thereof. Ordinary humans spend practically one-third of their span of life in bed. Therefore, we may properly assume that ordinary humans possess knowledge of the mechanism of an ordinary wooden bed. . . . The wife not being a party to the contract of purchase, cannot maintain this action."

If the wife could not hold the dealer, how could she hold the manufacturer who is even more remote?

In New York State, at least, there is a procedural way of placing the liability on the wrongdoer-manufacturer by bringing him into the suit when the plaintiff sues the dealer from whom he bought the product. If the plaintiff recovers from the dealer for breach of a warranty, the retailer can hold the wholesaler, who in turn can ultimately hold the negligent manufacturer (37).

All in all, until such time as the courts equate the ending of the privity requirement in food and drug cases to all other products, plaintiffs must continue to go against the manufacturers in tort for negligence (38). Of course, there could be a going back to earlier times and a finding that the duty of the manufacturer is described by any warranties he does or is bound by law to make.

If the manufacturer fails to live up to these implied in law warranties, then he will have breached his duty to the plaintiff. But to go this far is to say that public policy requires stricter liability of manufacturers for injuries caused by their products. It is these public policy questions we turn to now.

III. What is the Future for Enterprise Liability?

We have seen from the foregoing survey of legal history as found in judicial decisions settling disputes between the injureds and injurers that there has been a tendency in more modern times to hold the agency causing an injury to a user liable to him on various theories of law, and no matter how remote the user may be from the manufacturer.

The earlier decisions in the 1800's tended to shield private enterprises from excessive liabilities for their injuries because presumably it was felt that economic development would not proceed at the necessary pace unless this were the case. But the good things of life have now been obtained in abundance, although at a large increase in hazards to the individual. "The search is to find a more comprehensive and more adequate means of protection for all victims of personal injuries and death, at least those resulting from the mechanized good things of modern society, without placing too heavy a burden on enterprise or any other segment of the social group (39)."

It would seem that the tendency of the courts has been to find liability even where there has been no *moral* fault, that is, even where there has been an absence of any desire to cause the user harm. Yet our law of negligence is based upon placing "blame" on the defendant if he does not act reasonably by guarding against foreseeable injuries to the plaintiff. That this may not be a satisfactory way of settling liability and providing compensation for the losses to injured users has been suggested by several writers (40).

What the law should want to know, according to Professor Albert A. Ehrenzweig of the University of California School of Law, is whether liability can be fairly imposed on the enterprise because the harm done was *typical* for its activities, and thus calculable and reasonably insurable by the enterprise. This quasi-strict liability would be imposed upon enterprise without consideration of moral fault and would "include injuries which, being typical for the particular enterprise, could have reasonably been foreseen (though not avoided without abandoning the enterprise) by the entrepreneur when starting his activity (41)."

Quite aside, then, from the years of efforts of manufacturers of machinery or equipment or materials in the forest products industries to produce safer products, it is clear that a certain number of accidents injuring persons and property (43) are inevitable. And quite aside from the theoretical, academic or judicial discussions of methods of "loss distribution," it is clear that the producer would do well to seek protection, probably most readily obtainable through insurance. Again, we do not mean to become embroiled in any discussion of the place of insurance in establishing liability for the kind of harm we have been considering here. Rather, we mean only to advocate the carrying of this type of coverage in the light of the quite obvious extension of the risk of doing business today on the part of the entrepreneur (43).

True, the business world is generally quite aware of this kind of insurance and its relatively low cost. Yet there are many producers who are without it. The user, of course, through the price mechanism will ultimately pay for this cost of doing business, but such diluted cost to him is an infinitesimal burden opposed to the possibility that no recovery upon a judgment will be had against an irresponsible producer of small financial worth.

Conceivably, too, it is possible for a group of related entrepreneurs to take out a single policy of insurance to provide this coverage, and thus reduce the amount of the premium somewhat.

Of course, as we hinted a moment ago, insurance against hazards of turning out products is not enough. The law demands that we measure up to certain standards of conduct by making us responsible, within the limitations noted, for the injuries we cause. We must seek to improve our processes of research, manufacture, assembly, inspection and maintenance to reduce the area of possible harm to users. While we may rely perhaps a bit longer on the doctrine that if a user contributed to his own injury the manufacturer may escape liability, we must also be realistic and observe that this doctrine is being replaced gradually by stricter liability on our part.

That the trends are as I have outlined is there for anyone to observe and study. We should take them into account and obtain protection from this area of risks of doing business, while the insurance industry and our courts, legislatures and universities seek better methods of distributing the losses suffered as a result the operation of our enterprise system.

Literature Cited

1. See Feldman, "Liability of Home Furnishings Manufacturers and Dealers for Harm Done by the Product," *Handbook of Furniture Manufacturing*, Furniture Manufacturers Association of Southern California (1954), p. 83.
2. William L. Prosser, *Handbook of the Law of Torts* (1941), p. 666. See, for a humorous treatment of the subject, S. J. Perelman, "Come on In, The Liability's Fine," *The New Yorker*, June 6, 1953, p. 37.
3. "Enterprise liability" is a phrase originated by Professor Albert A. Ehrenzweig of the University of California in his brilliant and

much referred to monograph *Negligence Without Fault* (1951).

4. Prosser, supra, note 2, p. 674.
5. Dalehite v. United States, 346 U. S. 15, 51. 73 S. Ct. 946, 976 (1953).
6. *The Common Law* (1881), p. 1. "The final cause of law is the welfare of society." Benjamin N. Cardozo, *The Nature of the Judicial Process* (1921), p. 66.
7. "For the reason that in the cases of the character which have been mentioned the natural and probable effect of the negligence of the contractor or manufacturer will generally be limited to the party for whom the article is constructed, or to whom it is sold, and, perhaps more than all this, for the reason that wise and conservative public policy has impressed the courts with the view that there must be a fixed and definite limitation to the liability of manufacturers and vendors for negligence in the construction and sale of complicated machines and structures which are to be operated or used by the intelligent and the ignorant, the skillful and the incompetent, the watchful and the careless, parties that cannot be known to the manufacturers or vendors, and who use the articles all over the country hundreds of miles distant from the place of their manufacture or original sale, a general rule has been adopted and has become established by repeated decisions of the courts of England and of this country that in these cases the liability of the contractor or manufacturer for negligence in the construction or sale of the articles which he makes or vends is limited to the persons to whom he is liable under his contracts of construction or sale. . . ." Sanborn, Circuit Judge, in *Huset v. J. I. Case Threshing Machine Co.*, 120 Fed. 865, 867 (1903).
8. *Winterbottom v. Wright*. 10 M. & W. 109, 152 Eng. Rep. 402 (1842).
9. He claimed he was "lamed for life." *Winterbottom v. Wright*, supra, note 8.
10. *Winterbottom v. Wright*, supra, note 8.
11. Ehrenzweig, supra, note 3, pp. 28–29.
12. Supra, note 8.
13. *Huset v. J. I. Case Threshing Machine Co.*, supra, note 7, p. 867.
14. Baron Alderson in *Winterbottom v. Wright*, supra, note 8, in his opinion denying recovery to the injured plaintiff said "The only real argument in favor of the action is, that this is a case of hardship, . . ."
15. 6 N. Y. 397, 57 Am. Dec. 455 (1852).
16. 56 N. Y. 124, 15 Am. Rep. 387 (1874).
17. Where a furniture dealer was apparently aware that a wall bed which he sold to a house owner was defective, but where he assured the owner that it was safe, he was held liable to the plaintiff (who was a roomer of the house owner) after she was injured by the collapse of the bed, even though there was no privity of contract between the roomer and store owner. *Lewis v. Terry*, 111 Cal. 39, 43 P. 398, 31 L.R.A. 220, 52 A.S.R. 146 (1896). Where the dealer knows of the defect he may be guilty of the tort of misrepresentation or fraud.

    Another exception has been recognized in other cases where defendant has created a nuisance. James, "Scope of Duty in Negligence," 47 *N. U. L. Rev.* 778, 798 (1953).
18. *Huset v. J. I. Case Threshing Machine Co.*, supra, note 7.
19. 166 N. Y. S. 509 (1917).
20. Cardozo, *The Growth of the Law* (1924), p. 77.
21. 217 N. Y. 282, 111 N. E. 1050 (1916).
22. James, supra, note 17, p. 799. In *Okker v. Chrome Furniture Mfg. Co.*, 26 N. J. Super. 295, 97 A. 2d 699 (1953), it was held that there was a duty of care on the part of the manufacturer to an infant sitting on the lap of his father who was himself sitting on a bar stool when the swivel pin fractured sending them both to the floor.
23. *Kalash v. Los Angeles Ladder Company*, 1 Cal. 2d 299, 34 P. 2d 481 (1934). The jury so found in the plaintiff's favor, but a majority of the court reversed this judgment because it found the instructions too confusing on the issue of whether the manufacturer had been free from actionable negligence in failing to discover the dangerous condition of the defective rung. This was followed in *Sheward v. Virtue*, 20 Cal. 2d 410, 126 P. 2d 345 (1945), where the plaintiff was injured when the chair in which she was sitting collapsed in a beauty shop operated on the premises of a department store. The manufacturer apparently contended that although he did not inspect the steel tubing he purchased and assembled into chairs, neither did other manufacturers do so customarily. The Supreme Court of California denied the contention and said that the appropriate standard of care here was that if the defective condition of the part could have been disclosed by reasonable inspection and tests and such inspection and tests had been omitted, the defendant had been negligent. 20 Cal. 2d 410, 414, 126 P. 2d 345, 347.
24. See the plaintiffs' allegations and proof in *Simmons Company v. Hardin*, 75 Ga. App. 554, 43 S. E. 2d 553 (1947); *Kalash v. Los Angeles Ladder Company*, supra, note 23; *Sheward v. Virtue*, supra, note 23; Woodworkers Tool Works v. Byrne, (CCA 9) 191 F. 2d 667 (1951). See also Morris, "Proof of Negligence," 47 *N. U. L. Rev.* 817 (1953).
25. See Dickerson, *Products Liability and the Food Consumer* (1951) p. 112 and notes; *Sheward v. Virtue*, supra, note 23.
26. Dickerson, supra, note 25, p. 122. But where there is an intervening force leading to the injury the chain of causation leading from the manufacturer may be broken, relieving the defendant of liability. See, for example, *Stultz v. Benson Lumber Co.*, 6 Cal. 2d 688, 59 P. 2d 100 (1936), where the seller who sold a defective plank with knowledge that the plank was to be used to build a scaffold was held not to be liable for injuries sustained by buyer's employees who fell when the scaffold broke, since the defective condition of the plank was visible and known to the buyer who constructed the scaffold.
27. The Latin phrase, *"res ipsa loquitur"* (the thing speaks for itself), is used loosely to cover these instances where the plaintiff can only show that the cause of the accident was something which lay in the exclusive control of the defendant. In other words, he must introduce evidence to exclude the possibility that it was due to his own negligence, or that of the intermediate dealer or third person. When this is done, and particularly when it appears that the goods have reached the plaintiff in a container sealed by the manufacturer, an inference of negligence may arise, if the defect is one which ordinarily does not occur without negligence on the part of the maker. Whether the inference is to be drawn is a matter of common experience as to the particular facts. There are some defects in manufactured goods, such as minute foreign objects in food or bottles which do not necessarily indicate any lack of proper care. For an excellent discussion of this doctrine see *Escola v. Coca Cola Bottling Co.*, 24 Cal. 2d 453, 150 P. 2d 436 (1944).

"May the principle [*of res ipsa loquitur*] be properly applied in the case at bar? We conclude that it may. The circumstances as demonstrated by the evidence are such that the requirements of *res ipsa loquitur* are easily met. The broken part of the panel raiser head [which had been installed by the employer of the plaintiff on a shaper machine] was put in evidence. The blow holes and porosities of the fractured part are clearly visible to the naked eye, even without regard for fracture lines. There was testimony that prior to the painting of the device by Woodworkers Tool Works the imperfections were all the more apparent. There was evidence that the imperfections could have been discovered by ordinary visual inspection. There was also evidence that the large blow hole would have been readily disclosed by X-ray examination. The defects were and could have been caused only in the casting of the metal. They could not have been created by rough handling in shipment or by error in installation. The castings were made by Gunite Foundries of Rockford, Illinois, according to the testimony of Nourek, and the panel raiser head was made by Woodworkers Tool Works from these castings. It follows therefore that Woodworkers Tool Works may be found to be legally liable for Byrne's injuries." Woodworkers Tool Works v. Byrne, (CCA, 9) F. 2d 667, 673 (1951). The case, however, was sent back to the lower court for further evidence as to whether service had been properly obtained against the Illinois manufacturer by service upon its sales outlet in California.

28. California Civil Code, Section 3333.
29. 106 Cal. App. 2d 650, 235 P. 2d 857 (1951).
30. To use illustrations from the furniture manufacturing industry only, see *Sheward v. Virtue,* supra, note 23, and *Lill v. Murphy Door Bed Company of Chicago,* 290 Ill. App. 328, 8 N. E. 2d 714 (1937).
31. *Phillips v. Ogle Aluminum Furniture, Inc.,* supra, note 29.
32. See the section on "Damages," supra.
33. See, for example, *Klein v. Duchess Sandwich Co.,* 14 Cal. 2d 272, 93 P. 2d 799 (1939). But opposing this view, see *Smith v. Salem Coca-Cola Bottling Co., Inc.,* 92 N. H. 97, 25 A. 2d 125 (1942).
34. Uniform Sales Act, Section 15; California Civil Code, section 1735.
35. *Baxter v. Ford Motor Co.,* 168 Wash. 456, 12 P. 2d 409 (1932); *Bahlman v. Hudson Motor Car Co.,* 290 Mich. 683, 288 N. W. 309 (1939). The defense of contributory negligence is not available to the manufacturers in these actions.
36. *Jaroniec v. C. O. Hasselbarth, Inc.,* 223 App. Div. 182, 228 N. Y. S. 302 (1928).
37. N. Y. Civil Practice Act, Sec. 193-A. See, as an illustration, *Poretz v. R. H. Macy and Co., Inc.,* and *R. H. Macy and Co., v. New England Co.,* 119 N. Y. S. 2d 211 (1953).
38. In the case of *Burr v. Sherwin Williams Co. of California,* 118 A. C. A. 379, 258 P. 2d 58 (1953), plaintiffs suffered crop damage after spraying their acreage with defendant's spray. There was a count in warranty as well as in negligence, and the court sustained it even though there was no privity of contract between the plaintiff and the manufacturer: "The rule enunciated in the Klein case [supra, note 33] appears to be that a manufacturer of an article which is inherently or imminently dangerous or which, although not dangerous in itself, becomes so when applied to "its intended use in the usual and customary manner, is liable to any person whether the purchaser or a third person who, without any fault on his part, sustains an injury which is the natural and proximate result of negligence in the manufacture of the article if the injury might have been reasonably anticipated. In such case, liability does not depend on warranty nor does it depend on privity of contract. It is said in such cases that liability depends rather on a breach of a public duty owing to all persons into whose hands the article may lawfully come and by whom it may be used. 65 C. J. S. Negligence, section 100, p. 622. This rule has been applied to food and drug cases intended for human consumption, and might properly be extended to chemicals which are contaminated and therefore unfit for the purposes for which they are compounded and the uses and purposes contemplated by the label under which they are sold."
39. Green, "The Individual's Protection under Negligence Law: Risk Sharing," 47 *N. U. L. Rev.* 751, 775 (1953).
40. Notably Ehrenzweig, note 3, pp. 86–87; also Ehrenzweig, "A Psycho-analysis of Negligence," 47 *N. U. L. Rev.* 855 (1953); Ehrenzweig, "A Non-Compulsory Automobile Compensation Plan, 'Full Aid', not 'First Aid,'" (manuscript not yet published, 1954); Green, supra, note 39, at page 776. Professor Ehrenzweig's views have been widely discussed, but not necessarily with unanimous approval. See, for example, a review of *Negligence Without Fault by John Alan Appleman,* 47 *N. U. L. Rev.* 933 (1953). Favoring a stricter liability see also Dickerson, supra, note 25.
41. Ehrenzweig, supra, note 3, p. 61. See also, Green, supra note 39: "It would be possible to develop a comparative risk sharing arrangement supported in part by compulsory comprehensive loss insurance required of owners of all machines and employers engaged in dangerous operations of every character coupled with comprehensive accident insurance for the operators of such machines and employees engaged in dangerous operations, by which risks of personal injury, death, and property damages could be shared by the individual and the group on a basis of all the data involved in the tragedy." p. 771.
42. Whether a plaintiff could recover in negligence from a manufacturer with whom he was not in privity for injuries done to his property was a question carefully left undecided by Mr. Justice Cardozo in *MacPherson v. Buick Motor Company,* supra, note 19, but the law now holds generally that such liability exists. See, for example, Feezer, "Tort Liability of Manufacturers," 19 *Minn. L. Rev.* 752 (1935).
43. The "product hazard" is defined in the General Comprehensive Liability Form of insurance in the following words:
"The handling or use of, the existence of any condition in or a warranty of goods or products manufactured, sold, handled or distributed by the named insured other than equipment rented to or located for use of others but not sold, if the accident occurs after the insured has relinquished possession to others and away from premises owned, rented or controlled by the insured."

Reducing the High Cost of Information by Using the Statistical Approach to Research

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It is possible to reduce the high cost of research information by using statistical methods to design and analyze experiments and to discriminate between sets of research and production data. The application of sound statistical methods to research will result in more information of a higher quality in less time than is possible when such methods are not used.

The author presents the conditions which must be met if research workers are to take advantage of the increased efficiency offered by the application of statistical methods. Specific examples are cited of the types of problems which are suited to statistical treatment and the advantages gained by such treatment are brought forth.

Introduction

MEMBERS OF THE Forest Products Research Society as a whole probably fall into one of two categories: (1) those who are directly or indirectly concerned with acquiring information relative to forest products or to the forest products industry and (2) those who are concerned with applying such information to various phases of marketing. The chances are that most of our information comes to us in three general ways: (a) It comes in written form from outside our own organization; (b) it is acquired by the direct, uncontrolled experience of ourselves or those within our organization; or (c) it originates as the result of the controlled experience of ourselves or other people within our organization.

Have you ever thought about the cost of the information which we are prone to take so for granted? Consider the first category, the printed word from outside sources. It comes, for example, from books, trade journals, the Journal of the FPRS, and Forest Products Laboratory reports. Though it is relatively inexpensive, this type of information often is not too pertinent to our own problems, our own product, our own process; otherwise why would we have research departments?

The second category is a more costly type of information—that gained by personal experience. It has cost us time. The amount of useable information we have depends partly on our formal training, partly on the pertinence of the job experience which has led up to our present occupation, and partly on our individual faculties of intelligence and alertness. Of course, this type of information is difficult to evaluate dollarwise, and the improvement of the quality of information gained by uncontrolled personal experience is outside the scope of this paper.[1]

Now consider the third category—that information which originates as the result of our own—or someone else's—controlled experience. We might call it research. Does it cost much? Yes it does, we agree, but how much?

The closer we are to the research effort the more we appreciate how costly the useable information we get from research must be. How often do the results we get after a prolonged effort lead us to ask questions of this sort: "What have we really learned that's worth knowing?" or: "Now that we have reached a conclusion what do we do with it?"; "How applicable are the conclusions to our product or process?"; "Were the limits of the experiment really too narrow to make the conclusions valuable?" Thoughts like this provoke the mind of the critical reviewer who may be led to doubt the practical nature of the results as well as their reliability.

The technical director of a large wood adhesive company estimates the cost of research time to be five to six dollars per hour. When a price tag like this is attached to research one wonders if it needs to cost so much for the amount of information received or whether more information might be extracted per dollar of invested time.

At this point in an examination of the high cost of information there may be a willingness on the part of those who are dissatisfied with the return on research investment to inquire into the truth of the assertion that the application of sound statistical methods to research will result in more information of a higher quality in less time than is possible when such methods are not used.

No attempt will be made in this paper to give a short course in research methods, but an attempt will be made to establish the logical economic place of statistical applications to forest products research and to point up their advantages by using specific examples from several phases of the forest products field.

Is the Statistical Approach to Research New?

Statistical Quality Control is a tool which only recently has been given attention by the forest products industry although SQC methods have been practised in other industries for a longer time. A glance at FPRS Journals for the past few years and at the program for this annual meeting is sufficient to indicate its growing importance in the wood industries. Statistical methods used in designing experiments

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[1] An interesting and humorous non-technical treatment of this subject may be found in a book by Kenneth S. Keyes, Jr. How to Develop Your Thinking Ability. McGraw Hill, N. Y. 1950. 246 pp, illus.

and analyzing data are to research what SQC is to production. Just as SQC was perhaps a bit slow in being accepted in the woodworking industry, the use of research statistics also seems to be getting off to a slow start.

The statistical approach to research has been tried and found satisfying in other industries as evidenced by the ever-growing list of books on the subject.[2] It is already in use in some phases of the woodworking industry where research is being carried out. Now it appears to be just a matter of time before we will see more evidence of statistical methods being applied—and misapplied—to forest products research. Certainly the promotion of the possibilities offered by the statistical approach falls clearly within the stated purpose of the FPRS.

Workers in the field of silviculture and forest mensuration were quick to learn how to apply statistical designs and analysis to their research problems. They were able to translate published examples of statistical application in the field of agriculture—where its usefulness was already established—to forestry research problems. It has been nearly 20 years since the first popular work was published on the application of statistics to forest mensuration and slightly more than that since it first was taught in forestry schools.[3] The U. S. Forest Service has conducted a school of statistics for research workers from the various branch experiment stations for about two decades.

The foregoing evidence does not mean that advantage is always taken of statistical applications in forestry research. Indeed, experience has shown that it can be misapplied to the point where even common sense can be pushed to the background when the worker becomes the servant of statistics instead of statistics the servant of the worker.

Why Not Statistical Applications in Forest Products Research?

There are probably a number of reasons why little advantage has been taken of statistical methods as applied to forest products research. Chief among these is the fact that research workers in the forest products field come from such diverse backgrounds. We are, in general, chemists, chemical engineers, mechanical or civil engineers, and graduates in wood technology. What we are largely depends upon the background requirements of our particular work.

With few exceptions, most of us have not been trained specifically to do research work in forest products. Of those who have—perhaps men with graduate experience—most of us have had little or no exposure to statistical methods, especially as regards the philosophy of sampling and the design and analysis of experiments where several variables are studied at two or more levels each. Several schools of forestry offer courses in statistical methods at either the upper division or graduate level so that a few students in wood technology are able to attain a fair grasp of statistical principals as they apply to their own particular field of interest.

Another reason why statistical methods are not more widely used in forest products research may be due to the lack of adequate books on the subject. There is a growing list of excellent reference books on statistics, but in some cases they are directed toward a particular field, and in others, attempt to be both general in purpose and all-inclusive in scope. Thus, it is difficult for a research worker to find a single book which will take him from a beginner's knowledge of statistics to the point where he can apply statistical methods to the problems at hand without the expenditure of a great deal of study time.

There are several impediments to the efficient expenditure of time in studying statistics. One is the conflicting—and often confusing—symbology and terminology among statistics books. Another is the difficulty of the beginner in translating examples dealing with agriculture or biology to research problems in forest products.

The enthusiastic planning of technical directors, section chiefs and coworkers to adopt a statistical approach to research must take the factor of human prejudice into account realistically if disappointment is not to come early. Prejudice manifests itself in several ways: in the reluctance to give up the old way, the easy way, of varying one thing at a time in experimentation; in the reluctance to accept the idea that another approach to research might be better than the present approach; in the reluctance to inspect critically the premises and assumptions which are the basis for the present pattern of research; and in the reluctance to make the effort to acquire the habit of this "new" way of thinking and operating which makes the old way, in retrospect, look hopelessly inadequate.

How Can Research Workers Learn Statistical Methods?

It is not intended here to present a discouraging outlook to those who would like to use the statistical approach to research. In the space of only a few months a research organization may be well along the way toward establishment of an efficient, sound, statistical approach to research problems. Good progress for an individual requires that four conditions be met. Listed in order of suggested priority these are:

a. A genuine interest in the possible improvements in research efficiency offered by the statistical approach.

b. Sufficient background reading for a good exposure to the elementary concepts and terminology of statistics.

c. Guidance in the planning and analysis of an experiment by a coworker with some experience in statistics or by an outsider — preferably someone who is conversant with the worker's field.

d. A specific experiment or set of experiments in the planning phases to provide personal experience with data collection and manipulation and to get the "feel" of the mathematical logic which need not be understood explicitly.

Short courses in statistics for research workers are not satisfactory for the meeting of all four of the conditions listed. Seminars of this sort may serve as a substitute for the reading phase. This stage of the learning process also may be shortened considerably by using a prepared outline or summary of the essential features of beginning statistics, particularly if examples of familiar data are used. But in the final analysis, some individual guidance by a competent person is almost essential if a research worker is to reach the point where he can develop statistical ability on his own. At this point he can learn much from the many adequate reference books on the subject.

What Kind of Problems?

Statistical methods can be applied to a great variety of problems of the type which are likely to confront research and product development personnel. Problems may vary considerably—from discriminating between two sets of production data to highly complex experimentation which requires a research committee, an elaborate statistical design, a long period of time, considerable expense, and, perhaps, even the services of a statistical mathematician. The author is concerned with the application of practical statistical methods of the type which one man may use to design, execute and analyze an experiment in a relatively short period of time, i.e. from one man-day to about two or three man-weeks of actual effort, depending on the length of time required to collect and analyze the data. At this level statistics becomes a

[2] Youden, W. J., 1951. Statistical Methods for Chemists, Wiley & Sons, N. Y. 126 pp., illus. Brownlee, K. A., 1953. Industrial Experimentation, Chemical Publishing Co., N. Y. 194 pp., illus.

[3] Bruce, D., and Schumacher, F. X. 1935. Forest Mensuration, McGraw Hill, N. Y. 360 pp., illus.

"bread and butter" adjunct to everyday research.

Discriminating Between Two or More Sets of Data: The application of simple statistics makes it easy to put mathematics to work in making decisions about two or more sets of data. For example, an importer wishes to determine whether Japanese white oak is as strong in bending as American white oak by making a few tests on representative samples of the former. If ample data on American white oak are available the answer can be obtained easily, otherwise it will be necessary to make somewhat more extensive tests involving the American species.

Industry problems often are of this sort: A hardboard manufacturer wants to know whether representative samples of his competitor's product indicate that his own hardboard is likely to be just as strong or stronger in bending, just as low or lower in water absorption, etc. He has, of course, ample information on his product, so the problem involves consideration of the reliability of one small sample. Another example of a similar problem is as follows: A technical service man for an adhesive company wants to know how he can tell, on the basis of a few measurements of viscosity, if a customer is mixing his glue in the proper manner. Sufficient data are available which provide him with a good estimate of the average viscosity of the glue when it is well mixed, but he knows that small samples only provide rough estimates of the true viscosity. In each of the above examples the use of statistical methods permits one to relate the data of the small sample to the measurements of a large sample so that the probability of difference can be estimated with accuracy.

Perhaps a more common problem concerns discrimination between two or more sets of data, as in the case of a paper manufacturer who has two machines making the same kind of paper. The question comes up: Is the quality of the two sheets the same? First of all, does the paper from the two machines exhibit about the same degree of variation in properties, and if so, is the average strength the same or is it likely to be different for paper from the two machines? This type of problem has unlimited application in the hardboard, particle-board, and plywood industries as well as in situations where we may wish to draw conclusions about the difference between two machines, two or more species compositions, two or more chemical additives, two shifts of personnel, the two ends of a press, etc. Problems of this type are usually handled by tests known to statisticians as the "sign" test, the "t" test, and the "F' test, or by a simple analysis of variance, depending on the circumstances.[4]

The Importance of Studying Two or More Factors at Once: The research worker who uses the statistical approach soon learns that it is inefficient to set about collecting data with the idea of measuring just one variable under two or more conditions as in the examples cited above. For the same amount of effort he can introduce a second variable and get three times as much information which is likely to be much more valuable to him. To illustrate, a student wished to make a study of the effect of the hook angle of band saw teeth on cutting efficiency. He was encouraged to include the variable of species along with hook angle. The introduction of the second factor to the experiment extended its scope but not its size. The student discovered that cutting efficiencies of Douglas fir and yellow birch did not respond in the same way to changes in hook angle. In other words, one cannot generalize about hook angle without a qualifying statement regarding species. In addition to this important interaction of hook angle and species, the general effect of hook angle and of species were evaluated separately.

It is rather dangerous to draw broad inferences from research data which have been collected by the conventional scheme of trying to hold all variables constant except one. Interactions such as that between hook angle and species are usually present in any research involving wood.

Often the study of two factors at once is not sufficient if practical conclusions are to be drawn from the data. Indeed, as the research worker becomes increasingly sensitive to the fact that one cannot validly hold too many variables constant, the problem of choosing the most important variables to study looms large. Thus in the experiment cited the student's attention was called to the fact that, after all, moisture content was a very important factor which might influence the optimum hook angle for one or both of the species used. Still another variable was introduced into the design with very little increase in attendant effort. This resulted in more than twice as much information than if only two variables were studied, because the following effects and interactions were studied: hook angle, species, moisture content, hook angle and species, hook angle and moisture content, species and moisture content, hook angle and species and moisture content.

In the field of plywood gluing we have learned that many of the variables formerly held constant strongly influence the experimental results. If one wishes to study a new resin for an adhesive compared to resin which has proved satisfactory, he may wish to try out the new resin (and the old) under conditions involving two or more mixes each. Other factors which have been shown to be important must be considered. These include: press time, assembly time, type of stock (e.g. species, heart or sap, hard-grained or soft grained, loose or tight peeled, rough or smooth, and the manner in which the veneer was dried), panel construction, resin solids, spread, and moisture content. For exploratory work safe assumptions can be made about some of these factors, but as it becomes desirable to learn more about a particular glue or set of glue mixes, certain of the factors must be worked into the experimental design if complete and meaningful information is to be obtained. Experiments invloving three or four of these variables have been found to be practically useful by forest products research workers. Most of these experiments fall into a category which is known to students of statistics as the randomized block type of experiment analyzed by the so-called analysis of variance technique.

Information obtained by statistical experimentation has proved to be very useful to sales and service personnel who are constantly confronted with the prejudices of product users which have resulted from their biased, uncontrolled experience.

Using the Statistical Approach to Refine Experimental Techniques: As research workers learn to adopt the statistical approach they often discover that former testing procedures are not as sensitive to the variables under consideration as they had hoped. Results may not be reproducible. It then becomes necessary to track down these sources of experimental error. Workers in the field of wet-strength resin development were able to improve greatly their techniques for making and testing hand sheets by the simple expedient of adding an extra variable to the experimental design every time a new experiment was run. Thus while the main purpose of an experiment may have been to study several resins at three concentrations each, a factor related to technique such as position in the sheet from which specimens were tested, press temperature, the nature of the conditioning period, the age of the pulp, etc. was introduced into the experiment at two or more levels. Each experiment provided another step in increasing the sensitivity of subsequent research, yet very little more effort was involved.

[4] A simple method for discriminating between paired data was presented recently by the author: Bryant, Ben S., 1953. The Effect of Incising on the Bending Strength of Crossarms, Jour. FPRS, Vol. 3, No. 2.

Using the Statistical Approach to Develop a Suitable Testing Criterion: In new areas of research it is sometimes necessary to make decisions as to which of several possible criteria is most suitable as an evaluation of product quality. For example, workers concerned with a particle-board process wanted to determine which of several types of tension and shear tests were most suitable as a primary criterion of board quality. A researcher investigating factors which affect the checking of plywood was faced with the initial problem of how to evaluate the degree of checking by some quantitative criterion. In each case the problem was solved by designing a simple two-or three-factor experiment as a result of which differences in mechanical properties, or in the degree of checking, as the case might be, ought to exist. The experiment was then analyzed separately for each of the several criteria. That criterion which proved to be most sensitive to the differences which were built into the experiment was given the greatest consideration as the criterion to adopt for future work. Notice that at the same time that doubt about the feasibility of the several criteria was eliminated by the mathematical procedure, the exploratory phase of the research was already under way. Information was obtained in each case which greatly influenced the design of future experiments.

Applying Statistics to Problems in Correlation: It sometimes happens that two variables, such as specific gravity and modulus of rupture in wood or hardboard, appear to be closely related. It may be desirable to relate these variables in such a way that one can be estimated from the other or, at least to see how closely related they actually are. Perhaps a third, equally important factor such as the degree of fiber refinement is not as closely controlled as was thought. Its relationship also can be investigated along with the other two. For example, it is possible to put mathematics to work to check the assumption that percent wood failure on exterior-test Douglas fir plywood chips is a better index of long-time resistance to delamination than is shear strength. The three variables are percent wood failure, shear strength, and percent delamination of matched specimens subjected to cyclic exposure. The technique used where three variables are involved is known as partial correlation.

What Is Gained by Using Statistical Data?

The student of statistical methods soon arrives at a point where it dawns on him that in statistically analyzing a set of experimental results he is, after all, only applying common sense. At the time of this revelation he may wonder why he bothered to go through the arithmetical manipulation when he might have come to the same common-sense conclusions without it. The mathematician La Place pointed out that the theory of probabilities is really only common sense reduced to simple calculation. The student upon reflection realizes that the use of statistical methods has served to temper as well as to reinforce his own judgment as to the relative meaningfulness of data.

Equally important, the use of statistical methods in every-day work enables research personnel to plan experimentation so as to minimize the incorporation of unintentional bias. Its use encourages them to record data in certain patterns and combinations which makes it easy to discover the real "meat" of the experiment.

Statistical design and analysis permit the worker to study the significance of more variables as well as important combinations of variables which cannot be studied by usual techniques. This added information is usually gained without greatly increasing the size of the experiment and the additional time required for its completion is never appreciable.

The most important advantage of all, perhaps, is that the statistical analysis of experiments involving several factors often enables the experimenter to discover in his data valid information which would otherwise remain hidden from the unaided mind.

The advantages offered by the statistical approach to the every-day effort of discovering useful information by means of the scientific method serve to minimize the high cost of this information as well as to increase its usefulness.

Canadian Standard Specifications and the National Building Code

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Profiting by experience elsewhere, Canada is fortunate that in its present stage of growth and industrial development a concerted effort is being undertaken to standardize material specifications, industrial and construction procedures through one national organization. Similarly, the development of a Building Code, designed for national coverage, using standard specifications wherever possible, represents a determined attempt to simplify a problem often made unduly complex by conflicting regional codes, standards and building by-laws.

Introduction

IT IS ALMOST SELF-EVIDENT that any person or organization engaged in the retailing, manufacturing or construction fields will be sympathetic to standardization. More often the individual firm asks how such standardization can be accomplished with minimum cost to the individual firm, how it can be enforced and how a demand for standardized products can be encouraged. Largely on the basis of overall savings with the threat of economic obsolescence, plus the probability of arbitary standards enforced by large purchasers, the major Canadian producers have subscribed to a voluntary system of self-standardization. Similar reasoning has produced active support by industry for a comprehensive National Building Code.

Scope

It is the purpose of this article to outline briefly the history and present organization of the Canadian Standards Association and the National Building Code, the fields they cover, and how they operate. In particular, the position of the wood products industries will be outlined, the limitations of standards pointed out and the problems faced by the wood products industries brought to your attention.

C.S.A. Organization

The Canadian Standards Association is a national association of technical committees with members representing producer, consumer, scientific and technical societies, inspection interests, educational institutions and government departments both federal and provincial.

The C.S.A. was incorporated under the Dominion Companies Act, in 1919 under the name of the Canadian Engineering Standards Association as a nonprofit, nongovernmental organization to provide a national standardizing body for Canada. It maintains close contact with thirty similar organizations in the British Commonwealth and foreign countries. It became the Canadian Standards Association in 1944 when the scope of activities was extended to an unlimited field of standardization.

The C.S.A. Board of Directors consists of 18 directors elected by the membership of the association and two appointed directors; the President of the National Research Council and the Chairman of the C.S.A. Technical Council. The Board may appoint 3 to 6 of its elected members as an Executive Committee which shall exercise, during the time the Board is not in session, such authority as is delegated to it. The Board of Directors appoints an Advisory Committee of individuals, such as eminent industrialists, conversant with and interested in the objectives of the association.

The Board creates a Technical Council of 50 to 100 members, nominated by and representing specific groups or interests. The Technical Council is the final authority within the Association of the approval of the technical provisions of completed proposed specifications prior to publication end of their subsequent revisions and amendments.

C.S.A. Sectional Committees

Sectional Committees are appointed by the Board of Directors for the development of standards. Sectional Committees exist in the following fields of standardization: civil engineering, mechanical work, electrical work, the Canadian Electrical Code, railway work, ferrous metals, nonferrous metals, timber, steel construction, welding and miscellaneous.

Sectional Committees tend to be comprised of senior technical staff members of the larger producer and consumer units nominated by industrial organizations major scientific, governmental and educational institutions, with chairmen of specification committees as ex officio members. The Sectional Committee on Timber is comprised of about thirty members, with Col. J. H. Jenkins, Chief, Forest Products Laboratories of Canada as chairman. Meetings are held annually and visitors with specific or contingent interests are invited.

The function of the Sectional Committee on Timber is to survey the requirements for standardization of timber products and their uses; as necessary, recommend and define the scope of new specifications review and as applicable, recommend by letter ballot the specifications as completed by its specification committees.

The following specifications have been completed and approved: (1) Structural Timber (second edition), (2) Glued Laminated Timber Construction, (3) Douglas Fir Plywood and Western Softwood Construction Plywood, (4) Hardwood Plywood, (5) Western Red Cedar Shingles and Machine Grooved Shakes, (6) Round Timber Piling (under revision), (7)

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Eastern White Cedar Poles (3rd edition), (8) Western Red Cedar Poles (2nd edition), (9) Wood Cross Arms.

The following specifications are under development: (a) Millwork; specifically Sash and Frames and Doors, (b) Wood Preservation; completed, awaiting printing, (c) Round Timber Piles (revision), (d) Engineered Design in Timber, (e) Wood Cross Arm Pins.

C.S.A. Specifications

It will be appreciated that the demand for a given specification may come from either the producer or the consumer or any interested party. A specification may be either a materials specification including quality control, inspection, testing and application or an engineering specification giving basic data, formulas, limitations and good practice. Some specifications combine both functions but this is not encouraged. Specifications must cover a broad subject, excluding proprietory articles and are basically minimum specifications designed to protect the consumer, standardize the product and product acceptance all within the practical capacity of the producer. Although not intrinsically a legal document they can become so by adoption, they can represent a minimum safe practise for legal purposes and they are used as the prime reference in the proposed National Building Code. Consequently a fairly rigid format for their writing is prescribed.

It is not claimed that C.S.A. Specifications are better than other specifications, indeed they copy extensively from other sources such as American Wood Preservers Association, American Society for Testing Materials, American Concrete Institute, etc. some of which are directly referenced in our building code. However, the setup of the Canadian Standards Association is an effective means of obtaining practical working standards suitable to all parties concerned and in the preparation of which Canadian interests are the media of formulation of such standards. It is voluntary, it costs money to all interested parties and there is no legal commitment unless misrepresentation of a C.S.A. standard occurs. Taken by and large it is run by engineers for the protection of the public. The C.S.A. has one great advantage—instead of a multiplicity of standardizing bodies, each perhaps important in its field, the C.S.A. is an organization which can be easily publicized. Some of the products standardized under it are bought directly by the consuming public. In the timber industries at least, producers of many products have found it easier to approach building inspectors, for example, with a C.S.A. specified product than when manufactured from other specifications either internationally recognized or of an association type, largely because competing materials come out under identical auspices.

A second advantage of the association is that specifications are designed for Canadian conditions, for example, climate factors, degree of industrial development, use of primary products. Normally Canada's imports, notably from the United States, exceed her exports. Where applicable, the specifications of countries exporting to Canada are considered and not with idea of exclusion on technical grounds. In many instances Canadian standards tend to parallel American standards and accepted practice. Incidentally about one hundred American companies subscribe to the Association.

C.S.A. Specification Committees

The chairman of a specification committee is normally appointed upon the recommendation of the Sectional Committee chairman. A good deal of latitude is allowed in the selection of committee members providing it is representative. Normally when any organization requests membership it is granted. No fee is required for membership of an individual in any committee and of course no expenses are paid by the association. Broad distribution of membership on a geographical basis is an essential element of C.S.A. Committee organization.

The scope of a particular specification is usually determined in advance but may be expanded or curtailed as circumstances dictate, subject to approval. Often a working committee is set up: its composition tends toward the producers and such scientific or government personnel as have adequate time. In Canada we are fortunate that it is the policy of the Forest Products Laboratories to both supplement and take an active part in Timber Specification Committees and much of the prestige of such specifications is attributable to that source. The liaison between the Canadian and American Forest Products Laboratories insures a common basis for our standards although they differ in detail.

The consumer is adequately represented both by active criticism and by vote. This fact is illustrated in the proposed organization of the new C.S.A. Specification for "Engineered Design in Timber" which gives an idea of the typical composition of a committee and its division of work:

Chairman—sales engineer, timber producing association.

Secretary—engineer, Forest Products Laboratory.

Sub committee—chairmen

General design—sales engineer, timber producing association.

Sawn timber design—engineer, Forest Products Laboratory.

Glued-laminated timber design—sales engineer, a laminating company.

Plywood design—sales engineer, plywood manufacturers' association.

Piles and pile structures—sales engineer, a creosoting company.

Including the above personnel, a breakdown of the committee membership is approximately as follows: Representatives of producers, 9; representatives of consumers, 6; government agency representatives, 6; forest products engineers, 4; university professors, 3; professional group representatives, 3.

With few exceptions, such people are professional engineers—the ones representing government tend to favor the consumer's point of view. The criterion of these committees is that they do work satisfactorily.

Each subcommittee will work out a draft within its terms of reference. Any draft, usually the work of one or two individuals, must satisfy not only the particular subcommittee but the committee as a whole, from both the engineering and legal aspects and it is usually the second or third draft which proves acceptable.

It is necessary to enter these C.S.A. committees with the belief that a specification for national coverage is either essential or desirable and to be prepared to make compromises to that end. Occasionally existing standards or common practice interfere with engineering compromises and other solutions must be sought. Following are two examples:

Under the terms of the C.S.A. Specification on Structural Timber all grading for structural timber, and all other engineering data is applicable to commercial species cut throughout Canada. Unfortunately, the common practice for sizing of lumber differs considerably between East and West, the eastern sizes being slightly larger. Therefore, disregarding the probable long term trend toward Western sizes (which are the same as American practice) it was decided that a table of both nominal sizes would be included in the specification but no change would be made in allowable knot sizes, etc. However the larger areas, Moments of Inertia and so on would apply to the eastern sizing, as mathematically derived.

In the second case, as the C.S.A. Specification on Glued Laminated Timber Construction was being prepared, it was found that the usual C.S.A. structural grades for joist and plank were not suitable for laminate stock and only the special classification for "tension members" applied. In the former, knot

sizes and placement are largely determining and in the latter, knot sizes and frequency. Further, no stress grade existed for 1-inch material.

It was decided to set up separate grades for 1-inch and 2-inch laminate stock to apply to all species, based on the "tension member" classification. The practical basis for this decision is that, in Canada, it is unlikely as yet that many mills will ordinarily cut stock for laminating purposes and that either a buyer's specificatiton will develop or that laminators will themselves regrade ordinary stock. It remains to be seen how this specification will work out, if it proves impractical it will be amended or rewritten as necessary. Meanwhile the public is adequately protected.

C.S.A. Subsidiary Divisions

The Canadian Standards Association includes two special departments:

1. A C.S.A. Approvals Division laboratory for the testing and approval of electrical and oil-burning equipment in the interests of safety in use, which may be enlarged in the future for testing of other equipment.
2. The Canadian Welding Bureau for testing and qualifying welding operators, supervisors and organizations in the interest of safe welding practice. Both subsidiaries operate on the basis of C.S.A. published standards.

C.S.A. Permanent Staff

There is, of course, a permanent staff for the Canadian Standards Association loacted at Ottawa. Their duties include general administration, editing, arranging for publication and distribution of standards, etc. The Canadian Standards Association publishes a quarterly bulletin giving a synopsis of meetings held, committees appointed, additions to membership and itemizes specification standards either proposed or completed. An annual list of current C.S.A. specifications is published. The C.S.A. subsidiary divisions are autonomous as to organization and financing and operate through administrative boards reporting to the C.S.A. Board of Directors.

C.S.A. Trade Marks

Provision is made to authorize use of registered C.S.A. Marks to producers manufacturing in compliance with C.S.A. published standards of quality and performance. The C.S.A. controls the use of its Marks and may invoke legal remedies and defend legal actions in the event of unproper or unauthorized use of such Marks.

This means of publicizing products complying with C.S.A. standards is good continuous advertising which tends to be self-expanding.

Distribution of C.S.A. Specifications

The C.S.A. maintains a stock of standards published by Standardizing bodies in a British Commonwealth and thirty other nations. These may be purchased through the association. Consequently, there is a constant demand for C.S.A. and other specifications on all kinds of subjects and wide coverage is obtained quite casually. In addition, many products carry a C.S.A. Mark and this leads to further inquiries. Companies and associations adhering to these specifications purchase them in bulk quantities at a substantial discount for wide spread distribution to interested persons. Finally, their inclusion in the National Building Code, as a prime reference source will greatly increase their effective range.

National Building Code

Perhaps there is no better way to outline this subject than to quote extensively from the introductory publication (August 1951) of the Associate Committee on the National Building Code, National Research Council of Canada.

"This is a brief statement of some of the questions which must be considered when arranging material in building codes and of the decisions which the Associate Committee has taken to improve upon the arrangement followed in the 1941 edition of the National Building Code of Canada.

"The complex character of building codes has long been apparent. At about the turn of the century, the codes then being used gradually ceased to be loose collections of isolated statements on safety in buildings, and began to take on the form so well recognized today. As codes developed in this way, the accelerated pace at which new regulations were added necessitated the broad grouping of similar requirements. This was found to be essential if any degree of efficiency of administration was to be maintained. From the great variety of groupings which then appeared, two main types evolved. A combination of these two groupings forms the framework of the majority of building codes in use today.

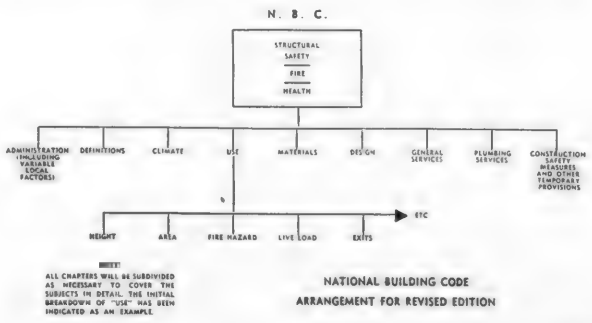
"These two systems are classed generally under the headings Subject and Occupancy. Occupancy groupings have been developed largely by municipal building officials since in their administration of building regulations they have had to think in terms of specific structures. Subject groupings, on the other hand, are primarily the product of scientific and research groups who have been able to view building regulations in terms of specific building problems which naturally group themselves around subjects rather than in relation to particular types of buildings. Naturally, there are many building codes which represent a compromise between the two main types of groupings, including many features of both.

"The arrangements of building codes currently in use have not, so far, succeeded in eliminating all difficulties of administration. Careful study has indicated that most of these difficulties are attributable to defects in the arrangement of the material which the codes contain. Problems of interpretation, duplication and inconsistencies within a code, and even lack of uniformity between different codes, will be found to stem from this root cause.

"Studies undertaken for the Associate Committee within the Division of Building Research of the National Research Council and extending for more than a year, have pointed the way to a new and unique system of arrangement. It appears to be logical and so should prove to be flexible and simple in use. The Committee have decided to follow it in the work of revising the National Code. If its use in this way proves to be as efficient as is expected, it may constitute an important contribution towards the development of greater uniformity in building codes generally throughout Canada.

"It might be supposed that the novelty of the new arrangement stems from an entirely new set of principles. This, however, is not the case, The idea of grouping regulations has been recognized from an early date. Attention has rather been concentrated upon the correct method of applying this principle; it is in this application alone that any novelty lies.

"A fundamental of systematic arrangement in building codes is the di-



NATIONAL BUILDING CODE
ARRANGEMENT FOR REVISED EDITION

rect association of a regulation with the object which is being controlled. Some requirements apply generally while others are restricted to particular parts of a building. General regulations should therefore always come first, detailed provisions being grouped appropriately under them. Understanding of this inter-relationship is essential to proper use of codes, detailed clauses being always read in association with the governing general requirements.

For grouping to be fully effective, it is equally essential that association of clauses be based on the causes of the various hazards to which the building may be subjected rather than upon their effects. For example, live loads and snow loads are usually grouped together even though live loads are due to occupancy and snow loads are the result of climate, the two causes being quite unrelated.

"Finally, the basic function of building codes must be recognized if their arrangement is effective. Essentially, building codes are regulations designed to ensure the safety of the public (in relation to buildings) with reference to public health, fire prevention, and structural sufficiency. These three determinants should be implicit in all relevant parts of a code; they will not, therefore, appear as separate sections of a code which can be considered without reference to the rest of the document.

"If the guides to logical arrangement herein suggested are followed, it should be possible to eliminate almost all of the duplications which so interfere with the use of many existing codes. Correspondingly, it should be possible to reduce the length of a code while improving its clarity. Most important of all is the possibility, presented by such a logical arrangement, of having a code any part of which can be amended without disturbing the remainder of the document, or requiring any change in the overall system of indexing and numbering.

"These are the objectives which the Committee has had in view and which it is believed are attained, to a considerable degree, by the arrangement shown in the chart to follow.

"It will be seen that each chapter, except the first, deals with some technical aspect of the safety of a building. All are subservient to an overall general statement defining the purpose of the code. The preparation of each of the new sections will be the responsibility of a special Technical Committee.

"The first chapter on Administration is the only nontechnical section. It is intended to include all necessary legal aspects of building regulations. It will therefore deal with such matters as permits, fees, and penalties. It will be seen that these are matters which may be, and usually are, subject to local variation. In this section, therefore, will be included all references to other regulations which may be related to minimum building standards, such as zoning ordinances and lot-occupancy requirements.

"Inclusion of Climate as a separate section of the Code represents, it is believed, another unique feature. If the Code is to be truly national, then it must take account of the wide variations in climate across the Dominion. This will entail the study of an immense volume of climatic data but the results of this will probably be depictable on simple outline maps, dividing Canada into climatic zones with reference to such technical matters as loads for heating design, wind loads and snow loads. Simple index references to these zones can then be made in other parts of the Code. These references will not be affected if, in the future, it is found necessary to change the boundaries of any of the zones.

"The concept of a separate main section of the National Building Code on Use (or Function) of buildings is in some ways the most interesting innovation. A large number of the features of building design which have to be regulated are determined by the use to which the building is to be put rather than by the material of which the structure is to be built, be it wood, masonry, concrete, or steel. Required exits, minimum room sizes, stairway dimensions—these and many similar features are independent of material but wholly dependent on the function which the building is to serve. Correspondingly, many of the loads which the building has to sustain are also determined by the use to be made of it, selection of a suitable structural material to withstand these loads being a subsequent part of building design. (Amongst the loads most clearly related to use are the internal fire loads which the various component parts of a structure must resist). By the grouping of all these functional requirements into one section, it is already apparent that great convenience will be achieved.

"The Materials section will present a listing of all common building materials, with reference to appropriate standard specifications where they exist, and with detailed specifications in cases where standards are not available. Regulations regarding the storage and handling of all materials will also appear in this section.

"Design is the section requiring least attention in this note since it is the most similar of all sections to the contents of conventional building codes. Given the loads (in Use and Climate), and particulars of the materials selected to resist them, the necessary limiting structural design will herein be defined, naturally with special reference to the main type of structure-of wood, masonry, reinforced concrete and steel.

"Modern buildings are equipped with many Services which, while not an integral part of the structure, constitute such vital components that their regulation must be included in any comprehensive building code. These parts of the revised National Code will therefore include a revised version of the Standard Plumbing By-law, and suitable references to such documents as the Canadian Electrical Code and the C.S.A. Safety Code for Passenger and Freight Elevators.

"The first eight sections of the new arrangement deal with the standards required of a building throughout its life, i.e., from its conception in the minds of its owner and designer and throughout its period of useful service. The last and ninth section will contain provisions of a temporary nature only; in some ways it, too, represents an innovation. During the construction of a building there are a number of necessary precautions which must be taken for the safety of those working on the structure and near to it, and for the protection of adjacent property. Similarly, when the time comes for a building to be demolished, specific safety precautions are necessary. Regulations dealing with these temporary requirements will be grouped into this last section, Construction Safety Measures, especially for the convenience of contractors who will be particular concerned with these provisions.

"Although it is aimed to have each section of the revised Code as complete unit in itself, there must naturally be the closest possible correlation of all the chapters, one with another. Through frequent consultation with the Chairman of the respective Technical Committees, the Associate Committee itself will guide this co-operative effort and will deal with the many general questions related to more than one of the sections which the work of revision undoubtedly will reveal.

"The National Building Code is a document which is national in scope and purpose. It is desired that it maintain its independent and national character. Accordingly, the task of preparing this first revised edition will be carried out by voluntary committees of experts—Technical Committees—representing all parts of the building industry and as many as possible of those concerned with the use of building codes in Canada.

"It is desirable that preliminary drafts of all revised sections should be circulated, before final approval, to all interested parties throughout the country. Correspondingly it is desirable that good publicity should be obtained for

the work of revision so that all concerned may know that the work is proceeding and that their comments will be welcome. The mechanics whereby this broad coverage of drafts is to be obtained will be worked out by mutual discussion, but it is intended that each provincial government and each municipal office shall either receive a copy of all drafts or at least advice that such drafts are available for study.

"In order that the Technical Committees shall work effectively and quickly, it is desirable that they be kept as small as possible, consistent with the work in view. The selection of the members of these committees will be the responsibility of the chairman, subject to approval by the Associate Committee. In so far as possible, members will be drawn from all parts of Canada.

"It will be necessary, in the case of some of the Technical Committees, to assign small panels to deal with particular parts of the main subject which is the responsibility of each committee. These panels will be nominated by the Technical Committees and should assist with much of the detailed work.

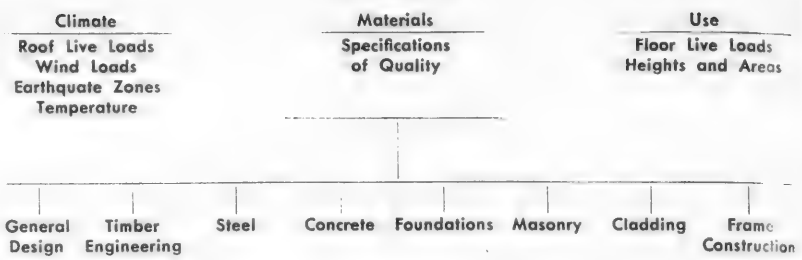
"Although no representatives of any organization are appointed as such to the Associated Committees of the Council, it will not only be possible but also desirable that representatives of some organizations should be appointed to the Technical Committees. Particularly is this true of the various trade associations concerned with any part of the content of the Code. It is hoped that all such bodies may be adequately represented on all appropriate committees.

"In addition to such interested parties, all Technical Committees and panels must have corresponding membership from what may be called 'consumer interests', i.e., architects, engineers, contractors and building officials who have no direct interest in the particular subject matter but who are concerned with its use in building.

"The National Building Code at present is both a specification and a performance code. Its more specific clauses have led to the criticism that it is unduly restrictive. Careful study has shown that incorrect wording and arrangement, leading to application beyond that intended, are usually responsible for this condition. Detailed as well as general regulations are necessary for adequate protection. The intended scope or coverage of each regulation should act as a guide in avoiding excessive restriction.

"Whenever possible, existing standard specifications are to be referred to and included as part of the revised code. These should be considered on the following basis of priority. Standard specifications of the Canadian Standards Association shall be used whenever available. When no C.S.A. specifications are available, those issued by the following bodies shall be considered in turn—Canadian Government Specifications Board; American Society for Testing Materials and/or American Standards Association; and thereafter the various specialized societies such as the American Concrete Institute. In using specifications prepared by specialized societies and by all industrial groups, preference will always be given to those documents in the preparation of which the consumer or public interest has been represented on all the appropriate committees".

CHART NO. II



It will be noticed that there is a considerable difference in presentation from more conventional codes. The inter-relation of various sections is illustrated in Chart 2.

Four portions in the design section are of interest to the forest products industries—(1) general design, particularly in so far as the fire resistances of structural elements are concerned. (2) Timber Engineering, which is concerned with structurally graded timber and wood products governed by C.S.A. specifications, together with fastenings. (3) Frame Construction which deals with the structural strength of good buildings not covered above and (4) Cladding which deals with the surfacing of structures.

Problems of the Timber Industries

Over the past several years work on the National Building Code and Canadian Standard Specifications has caused Canadian timber interests to review their position and focus their attention on outstanding problems, some of which require further research. Very briefly, some of these problems will be discussed.

Yard Lumber

In Canada, we see little chance of assigning stress values to lower grades on a national scale. In deed, to this date it has not been found possible to set up national grading standards for many species, although it has been done for structural grades. However, it is possible to relate the various species and grades to common end uses. A study is under way to determine if uniform grades for each species can be developed.

Specification Design

Specification design is mandatory and based largely on accepted practice. Wood frame construction is an excellent example. This industry is largely concerned with houses, few of which are engineered in an analytical sense whether or not this is desirable. There are several reasons for this condition—

(1) In some cases, performance instructions are either so simple as to be without meaning or so complex as to be ridiculous.

(2) Often, minimum safety requirements are not known.

(3) In many instances performance data is difficult to get or impossible to apply practically or represents too great a departure from accepted practice.

(4) The fastenings or applications of many materials are intrinsically mandatory and in some instances more important than the performance of the materials themselves.

The problems of frame constructions have received a great deal of attention. In some instances, in the housing field and in many commercial buildings some method of dealing with design variables is required. A slight change in the usual joist and rafter tables can produce a new and simple table which is useful over a considerable range of loading values. Essentially, it is a way of linking loads to spans by manipulation of joist and rafter spacing.

In structural elements which consist of multiple supporting units and in which load sharing may be assumed, it seems reasonable to assign a percentage of the permissible stresses of structural grades allowed for the species, providing the grade of the supporting unit is stipulated. This device would apply to built-up beams, decking, etc. and in effect allow performance design with yard lumber for such systems. Since most lumber is used in this way it seems a rewarding method of getting engineering values without assignment of stresses to lower grades.

Sheet Materials

Sheet materials, plywoods in particular, are increasingly being used in engineering designs. More often than with solid timbers the method of fastening is the determining factor of their actual strength and use. To govern the method of attachment, nail spacing for example, the manufacturer stipulates minimum requirements. These are mandatory based on experience, but they do not give basic engineering values. There remains the solution of performance tests of structural elements and its corollary, the standards of performance which are essential. The range of such tests can be extended from structural safety to acoustics, fire resistance and heat loss. Since other industries have equal interests, this would appear to be a developing field and one to which this industry should pay attention. As it is, any one can rig a test to prove some quality of a product superior to the competition and therefore recognized standards are going to be needed.

Fire Ratings

The complex problems associated with fire and fire ratings seem to be permanently with this industry. Many in the Canadian wood industries believe these problems require a specialist, expert on fire and fire prevention and are presently looking for such a man. In the near future, it appears likely that extensive tests are going to be devised to measure fire resistance, flame spread and other measurable quantities. C.S.A. Committee has been set up concerning Fire Tests on Building Coonstruction and Materials. The nature of these tests is important to this industry and so is the use made of the tests data. It seems essential that some correlation between this data and the performance of identical structures and materials in actual fires be established.

Summary

Probably the outstanding feature of the Canadian approach to codes and specifications is the producer-technician-consumer team for each special subject. Since it works, it can be regarded as a successful way to achieve the expressed aim of any code or specification, namely, to protect the public from substandard work. At the same time, these codes and specifications project the legitimate business interests from substandard competition.

Discussion

Mr. E. D. Marshall (Consultant in Forest Products): What features of the building code for laminating members are unpopular with the industry in Canada?

Mr. Thornber: We set up a tension grade in which the weakest cross section determined the strength of the whole piece. This has proven unpopular with laminators used to stresses based on knot frequency studies.

Mr. Marshall: Whay types of glues are recommended for laminated members?

Mr. Thornber: Glues are in categories for exposure conditions.

John Reno (Pacific Lumber Co.): Your method of grading laminated timbers sounds very expensive. Would your reason be that such timbers are intended for stock?

Mr. Thornber: Perhaps I misled you on that. We are dealing with many grades of several associations. An entirely new approach seemed reasonable with laminators regrading.

Ben S. Bryant (U. of Washington): In considering this load sharing, do you end up with higher working stresses?

Mr. Thornber: There's a tendency that way. We figure that for a particular end use, advantage can be taken of the capacity of members to share loads in average frame constructions. At least three supporting members must be involved, as in a built-up beam, rafters, studs, etc. The average piece for the grade and its statistical frequency is put to work.

D. V. Dierks (Dierks Lumber and Coal Co.): What happens where building codes are already established?

Mr. Thornber: During and since World War II, there have been vital changes in building materials and techniques so that many local building codes are out of date and admittedly in need of revision most municipalities will adopt a reasonable national code, adapted as necessary. We feel in the long run this will handle presently (adverse?) codes and by-laws. We cannot police the industry but encourage independent inspection.

Wood in Chemical Engineering Construction

R. H. BAECHLER

Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

The important role of wood in chemical engineering construction and the need for further research aimed toward its most effective use are discussed. Data are given showing the loss in bending strength of thin cross sections of 6 species exposed to 3 acids and 2 alkalies. Data are also given on redwood cross sections exposed to dilute solutions of 8 chemicals that are commonly present in water passed over cooling towers.

Introduction

WOOD IS EXTENSIVELY USED for construction in the chemical industry and in industries that are not commonly classified as chemical, but which use chemicals in their operations (9, 11, 12, 17, 20, 22, 23, 27). In these industries wood equipment or wood structural material may be exposed constantly or intermittently to a variety of chemicals that show wide differences in their tendency to attack wood. The resistance of wood to chemicals is, therefore, of considerable interest to the lumber industry and also to a large number of industries faced with the problem of deterioration by chemical attack.

Wood offers several advantages in chemical engineering construction; it may be selected in preference to some other material because of any one or a combination of these advantages.

Because wood generally costs less than competing materials, it is often used for processes for which it seems ill adapted. For example, wood tanks may be used under rather severe conditions during the early stages of a process when the marketability of a product is being explored. New industries are traditionally large users of wood equipment; as industries mature, wood may be replaced by other material for some uses, but not for others.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

ABOUT THE AUTHOR: BAECHLER, ROY H. Speaker, Session VI, General: "Effect of Dilute Solution of a number of Chemicals Which May Be Present in Water Passed over Cooling Towers" . . . Chemist in the Division of Derived Products, U. S. Forest Products Laboratory, Madison, Wis. . . . Received BS and PhD from the University of Wisconsin . . . Author of a number of papers on chemistry of wood preservatives which have appeared in the Proceedings of the AWPA and other publications . . . Member AWPA, ACS, AAAS, Sigma Xi, Phi Lambda Upsilon . . . FPRS charter member

Another inherent advantage of wood lies in the relative ease with which it can be fabricated. This is especially important in places where ready-made equipment cannot be moved readily. For this reason wood is sometimes used in contact with corrosive chemicals in less accessible parts of factories.

Wood is selected for some uses because of its thermal insulating properties. For example, by reducing heat losses, wood tanks make it easier to maintain uniform temperatures of materials being processed. They also help to keep work rooms from becoming uncomfortably hot.

Because of its electrical insulating properties, wood is used for separators and electrode supports in the electrolytic deposition of metals.

The tendency of wood to swell is an advantage in jordan fillers; they are invariably made of wood despite the fact that they are in contact with pulp that contains chemicals corrosive to wood.

Because wood is more readily available than some other materials, it is widely used in chemical engineering construction during normal times; during periods of shortages in strategic materials it is sometimes the only material available.

The advantages of wood that have been mentioned are well known; they are not specific to uses where exposure to chemicals is involved. A highly important advantage of wood that is less commonly appreciated is its resistance to mild acids. In this property it is far superior to common steel. While it is not equal to certain acid-resistant alloys, the high initial cost of these alloys in many cases results in a high annual cost.

For the construction of processing equipment, such as tanks and filter presses, the resistance of wood to acids not only increases the service life of the equipment, but also avoids objectionable contamination of the products. Wood tanks are still widely used in the manufacture of dyestuffs, one reason being that traces of iron reduce the brilliance of many dyes. Traces of iron also impart a metallic taste to foods; that is why wood tanks are used for processing sour foodstuffs, such as vinegar, pickles, and salad dressings.

Experience has shown that a tank used to store cold, dilute acids may last a long time. As the concentration of the acid is increased and, more especially, as the temperature is raised, the wood deteriorates more rapidly. Wood tank cars are used successfully for shipping cold concentrated hydrochloric acid, but the life of wood equipment exposed to hot concentrated hydrochloric acid would be very short.

Wood tanks used in pickling steel are subjected to unfavorable conditions, yet wood continues to be used for this purpose. In the pickling of steel, the products are immersed in acid solutions to remove oxides from the surface before they are given a protective coating, such as zinc or enamel. To reduce the time in the bath and thus increase output, acid concentrations and temperatures are kept in ranges that are known to be injurious to wood. An 8 percent solution of sulfuric acid, at a temperature of 150° F. or above, is commonly used. The thick timbers needed for strength in large tanks also reduce the deteriorating effect on wood. These timbers are of selected quality from the heartwood of species that resist penetration by liquids; this tends to minimize the acid concentration and temperature within the wood.

The life of a tank used in pickling steel is affected by a number of factors, including the workmanship of the builder, the care exercised by the user in such details as keeping rods uniformly tight, and the amount of mechanical wear accompanying the use. The service life is therefore variable; typically it is 3 to 8 years. Rubber-lined steel tanks have replaced wood tanks in many plants, especially where the pieces of steel can be held in baskets to avoid mechanical injury to the rubber. The wood tank appears to have lost little ground in batch operations involving miscellaneous shapes and sizes.

As might be expected, replacement cost of tanks is an important item in the overall cost of these operations.

Wood tanks lined with acid-resistant material, such as lead, have been used successfully for many years. For some uses, such tanks have completely displaced the unlined wood tank. A lower grade of wood may be used for this purpose. The wood supplies strength and thermal insulation while the lining serves to retain the liquid. This is an example of the efficient use of wood in conjunction with other materials.

Alkaline solutions attack wood more rapidly than do acidic solutions of equivalent strength. Since unalloyed iron shows high resistance to alkalies, wood is seldom used in contact with solutions that are more mildly alkaline.

Oxidizing chemicals are, of course, harmful to wood. Except in very dilute solutions, nitric acid is much more injurious than sulfuric acid. The action of chlorine and hypochlorite solutions is so drastic that wood is seldom used where resistance to these chemicals is required. On the other hand, wood tanks are fairly satisfactory for holding peroxide of hydrogen solutions.

Wood shows excellent resistance to most organic acids, notably acetic. Here it enjoys a distinct advantage over steel, concrete, rubber, and some plastics.

Wood tanks have been used for ages to hold brine solutions. While not all species are equally suitable, a well-constructed wood tank leaves little to be desired for this purpose.

Solutions of iron salts attack wood. The deterioration of wood in contact with iron (3, 19, 24) may be quite rapid under damp conditions, especially if the wood contains acidic extractive materials.

While tanks furnish striking examples of the deterioration of wood by chemicals, the problem goes much further. Structural members, floors, stairways, and duck walks are frequently exposed to splashing or spillage. Roof timbers, ventilating ducts, and stacks may be subjected to the action of volatile chemicals.

The deterioration of wood in cooling towers has received much attention during the past few years (3, 4, 5, 7, 8, 10, 13, 26). Two factors have been recognized, namely, decay caused by living fungi that utilize wood as food, and true chemical attack caused by substances in the water passed over the towers. Alkaline salts, especially sodium carbonate, and, in some cases, chlorine added in excessive amounts as an algaecide, are likely sources of chemical deterioration.

The possibility of protecting the wood from chemicals by a coating brushed or sprayed on the surface, or by some material injected into the wood under pressure, has been recognized for a long time and many materials have been tried (6, 21, 23, 27, 29). Some have been found to be effective and are in use today.

Wherever use conditions involve either mechanical abrasion, changes in temperature, or changes in moisture content of the wood, an impregnation of the wood with protective material might appear to be essential. In many cases, however, resistant coatings provide good protection. A coating generally costs less and it can be applied to the equipment after fabrication. A fair amount of effort has been devoted to the development of such coatings, not only by inventors but also by producers of wood tanks and by chemical companies. The chemical companies were seeking either to reduce maintenance costs on their own equipment or to develop a market for their products. Asphaltic and bituminous coatings have long been used and are still favored for some situations. A variety of coatings, such as modified rubber-base and synthetic resin types, have been tested and some have given good results for specific uses. Certain acid-resistant paints have been used in the dyeing industry although their function seems to be to make the tanks easier to clean rather than to protect the wood.

The difficulties of finding an effective coating increase with the activity of the chemical against which protection is desired. If pin holes are left in the coating or if checks develop with use, the underlying wood is quickly attacked and the adhesion between the wood and the protective film is impaired.

Despite the complexity of the problem, the difficulties are not insurmountable and research along this line should be continued. The rapid progress being made in the development of polymerized materials should be followed for its possible impact on this problem. Cooperation between fabricators and users of wood equipment should prove fruitful.

The relative value of species for a specific use is not subject to accurate measurement by laboratory methods. Nor are the results of practical experience completely reliable, because conflicting evidence is frequently found in service records. Large chemical companies would hardly depend upon snap judgment on a question involving a considerable capital investment; nevertheless two companies sometimes arrive at contradictory opinions regarding the relative merits of two species for a given purpose.

The heartwood of red (tidewater) cypress was for many years the predominant wood for the construction of chemical tanks. Dense southern pine heartwood also was used in large amounts. As the annual production of tank-grade material from these species declined, Douglas-fir heartwood came into increasing use. Redwood tanks have long been used to store chemical solutions. Spruce and white pine have also been used in considerable amounts, while still other species have found occasional use.

It is generally agreed that hardwoods are less satisfactory than conifers where resistance to acids is required. Oak tanks have been widely used for holding strong solutions of common salt (brine) and other chemicals that have a deteriorating effect unrelated to acidity or alkalinity.

A salient feature of the modern industrial age is the supplanting of trial and error by systematic research. However, not all problems are equally susceptible to modern methods of study. As in the case of protective treatments, questions involving the relative merits of different species for chemical equipment are frequently so complex that it is not feasible to reproduce in the laboratory the combination of factors prevailing in the plant. This does not mean that laboratory studies are useless. On the contrary, laboratory tests can be helpful in selecting species for equipment used in a new process. Even though laboratory tests do not give the final answer, fundamental laboratory studies are most likely to bring substantial progress in the efficient use of wood in contact with chemicals and in the development of protective treatments.

A number of laboratory tests on the effect of various chemicals on the physical properties of various species of wood have been reported in the literature (1, 2, 14, 15, 16, 18, 25, 28). Undoubtedly many unreported tests have also been made. No attempt will be made to review these studies. The results have varied due largely to differences in details of test methods. In all cases the investigators were aware of the limited applicability of their findings.

The resistance of wood to chemical attack depends upon the inherent resistance of the cell wall to a given chemical and the anatomical structure of the wood.

The anatomical structure governs the rate of ingress of the solution into the wood. The wood-preserving industry has found that different species show extremely large differences in their resistance to impregnation by liquids. In nearly all species the sapwood is more pervious than the heartwood. This goes far to explain why heartwood is superior to sapwood of the same species in resistance to chemical attack.

The experiments reported in the following section of this paper were set

up to find out if tests of thin cross sections could be used to study the inherent resistance of the cell wall of a species to a given chemical. This resistance is undoubtedly based largely on chemical composition. Although differences in the chemical composition of species are small they are of unquestionable importance. For example, certain generalizations can be made in a broad comparison of hardwoods and softwoods.

The alpha cellulose, which is the stable portion of the carbohydrate fraction, generally comprises in the neighborhood of 50 percent of the total extractive-free wood. Hardwoods as a rule contain larger amounts of hemicellulose, which is much more susceptible to attack by acids and alkalies than is alpha cellulose. The hemicellulose in hardwoods, which consists largely of pentosans, is more readily attacked than is the hemicellulose in softwoods, more than half of which consists of hexosans.

Softwoods contain somewhat higher percentages of lignin than do hardwoods. Lignin is fairly resistant to acids, especially cold dilute acids. It is more readily attacked by dilute alkalies, although not so readily as hemicellulose. It is quite susceptible to attack by oxidizing agents.

The extractives in different species vary greatly in nature and amount. Depending upon their chemical reactivity and the manner in which they are distributed, they may contribute materially to resistance to chemicals. The contamination of tank contents by extractives is objectionable for some uses and not for others.

To isolate the factor of inherent chemical resistance from the factor of anatomical structure, tests were made on cross sections because they could be readily impregnated. In this way the solution would promptly fill the gross cavities so that the internal structure of the wood would be subject to attack throughout practically the entire exposure period.

A preliminary series of bending strength tests were made on cross sections of 6 important species exposed to solutions of 5 commonly used chemicals. The method was then used to measure the reduction in the bending strength of redwood cross sections exposed to water containing low concentrations of chemicals that may be present in water passed over cooling towers. This second series of tests are discussed in the second part of the following section.

Experimental

1. Exploratory Tests on Different Species: Cross sections were cut from the ends of clear, seasoned, nominal 1- by 4-inch boards. They were approximately 7/8 inch wide by 3-7/8 inches long by 3/16 inch thick. The maximum variation in the thickness of 20 pieces selected at random was ± 0.003 inch.

Four softwoods—cypress, Douglas-fir, redwood, and southern pine—and two hardwoods—white oak and maple—were used in these tests.

An effort was made to select all-heart boards that were as flat-grained as possible with the annual rings showing low curvature. In this way the angle between the annual rings and the line of cleavage would be as consistent as possible. A southern pine board and a white oak board answering this description to the desired degree were not available. The oak board selected was nearly all sapwood. The pine was all heartwood but the curvature of the annual rings was greater than desired.

The chemicals used were sodium hydroxide, sodium carbonate, sulfuric acid, nitric acid, and acetic acid. Two concentrations, 2 percent and 6 percent, and two temperatures, 28° C. and 50° C., were used for each chemical. Several periods of exposure were used.

The cross sections were arranged in sets of five. To start a test, a set of cross sections was placed in a suction flask, weighted down with short pieces of glass rod, and covered with the proper solution. Vacuum was alternately applied and released until the cross sections were waterlogged. Next they were transferred to a pint jar that was then filled with fresh chemical solution. Control pieces of each species were treated similarly with distilled water.

Some jars were placed in an oven with the temperature controlled at 50° C. Other jars were placed on a shelf in a room in which the temperature was about 28° C.

After the required period of exposure, the pieces were removed and their surfaces rinsed free of the chemical solution. They were then tested for bending strength by means of a Tinius Olsen stiffness tester. The results in inch-pounds were compared with the results obtained on specimens exposed to distilled water.

In a preliminary series, the pieces were allowed to dry before testing. Because of checking, the results were erratic. Wet specimens gave more consistent results, so all data in this report are based on wet specimens.

One specimen of each set of five was allowed to dry and was observed for shrinkage and warping. The other four were broken and the data averaged. A few exceptions were made in

Table 1.—STRENGTH OF CROSS SECTIONS EXPOSED TO CHEMICAL SOLUTIONS EXPRESSED AS PERCENTAGE OF CROSS SECTIONS EXPOSED TO WATER

Item	HNO_3	H_2SO_4	CH_3COOH	NaOH	Na_2CO_3
CYPRESS					
2 percent solutions, 1 week at 50° C.	85.7	111.0	106.0	41.8	84.9
2 percent solutions, 2 weeks at 50° C.	78.8	97.3	105.4	35.1	72.7
2 percent solutions, 5 weeks at 50° C.	60.6	88.5	81.8	29.4	68.8
6 percent solutions, 1 week at 50° C.	59.8	101.2	100.0	----	73.2
6 percent solutions, 1 week at 28° C.	----	----	----	34.5	----
6 percent solutions, 5 weeks at 28° C.	74.6	92.6	98.8	33.4	74.5
6 percent solutions, 10 weeks at 28° C.	----	95.6	94.2	----	78.4
DOUGLAS-FIR					
2 percent solutions, 1 week at 50° C.	79.2	91.8	89.8	22.1	67.8
2 percent solutions, 2 weeks at 50° C.	65.2	97.7	98.5	21.8	69.2
2 percent solutions, 5 weeks at 50° C.	68.0	80.8	90.5	18.5	72.5
6 percent solutions, 1 week at 50° C.	36.2	88.6	87.6	----	67.6
6 percent solutions, 1 week at 28° C.	----	----	----	20.2	----
6 percent solutions, 5 weeks at 28° C.	52.0	84.9	86.2	24.0	68.5
6 percent solutions, 10 weeks at 28° C.	----	101.5	105.0	----	80.5
SOUTHERN PINE					
2 percent solutions, 1 week at 50° C.	80.9	95.9	106.0	29.1	70.3
2 percent solutions, 2 weeks at 50° C.	39.4	70.2	91.5	26.4	63.5
2 percent solutions, 5 weeks at 50° C.	49.1	72.2	93.5	25.0	73.3
6 percent solutions, 1 week at 50° C.	35.8	82.0	82.2	----	68.8
6 percent solutions, 1 week at 28° C.	----	----	----	23.5	----
6 percent solutions, 5 weeks at 28° C.	85.1	96.7	93.6	28.1	83.3
6 percent solutions, 10 weeks at 28° C.	----	102.0	106.0	----	89.8
REDWOOD					
2 percent solutions, 1 week at 50° C.	78.3	105.9	92.3	19.9	52.8
2 percent solutions, 2 weeks at 50° C.	50.3	87.2	102.2	19.0	53.0
2 percent solutions, 5 weeks at 50° C.	48.6	91.6	95.0	16.2	54.7
6 percent solutions, 1 week at 50° C.	37.1	92.3	92.7	----	55.4
6 percent solutions, 1 week at 28° C.	----	----	----	17.2	----
6 percent solutions, 5 weeks at 28° C.	52.5	78.3	89.2	19.3	50.1
6 percent solutions, 10 weeks at 28° C.	----	101.6	97.0	----	62.7
MAPLE					
2 percent solutions, 1 week at 50° C.	38.9	69.5	89.3	22.7	44.7
2 percent solutions, 2 weeks at 50° C.	85.5	60.3	103.8	19.6	43.3
2 percent solutions, 5 weeks at 50° C.	22.0	50.4	83.0	17.8	45.1
6 percent solutions, 1 week at 50° C.	9.4	50.4	89.4	----	41.7
6 percent solutions, 1 week at 28° C.	----	----	----	17.6	----
6 percent solutions, 5 weeks at 28° C.	28.2	61.4	87.7	17.9	58.3
6 percent solutions, 10 weeks at 28° C.	----	54.0	88.2	----	39.7
WHITE OAK (SAPWOOD)					
2 percent solutions, 1 week at 50° C.	44.1	78.9	101.5	20.6	44.1
2 percent solutions, 2 weeks at 50° C.	24.1	61.0	105.9	18.6	39.5
2 percent solutions, 5 weeks at 50° C.	24.6	40.8	91.8	17.5	40.6
6 percent solutions, 1 week at 50° C.	13.4	60.0	101.2	----	52.5
6 percent solutions, 1 week at 28° C.	----	----	----	15.0	----
6 percent solutions, 5 weeks at 28° C.	29.4	70.9	103.0	14.7	49.5
6 percent solutions, 10 weeks at 28° C.	----	82.5	108.5	----	63.3

the case of pine. When the breaking tests were being made it was observed that some of the pine cross sections that had been included deviated too much from the desired uniformity in the direction of annual rings. The results on such pieces were not included in the averages, which therefore were based on three tests in a number of cases.

The following observations were made regarding shrinkage and warping of dried specimens. The four softwoods showed less change in shape and length than did the two hardwoods. Of the chemicals used, acetic acid showed little effect on any species. Sulfuric acid caused the hardwoods to shrink and warp somewhat, but had very little effect on the softwoods. Nitric acid, sodium hydroxide, and sodium carbonate showed a little effect on the softwoods and a very pronounced effect on the hardwoods, especially maple.

The results of the strength tests are given in table 1. The data are arranged so as to facilitate comparison between chemical solutions rather than between species.

Not enough data are presented here to afford a fair comparison between different species. For such comparison, cross sections from a number of boards from each species would be needed and enough tests would be needed so that reliable averages could be derived by statistical treatment of the data.

2. Effect of Dilute Solutions on Redwood Cross Sections: Tests on redwood cross sections were made as part of a broad investigation of the deterioration of redwood in cooling towers. Decay is largely responsible for the deterioration in some cases. However, attack by chemicals in the water is believed to be an important contributing factor in some cases and the primary factor in others. The relative importance of the two factors is a matter of controversy at present.

The procedure used in these tests was essentially the same as that used in the first series. A set of controls for exposure to distilled water was taken from between two sets that were exposed to two concentrations of the same chemical. When only one concentration of a chemical was used, the values on the adjacent five specimens exposed to distilled water were taken as the basis of comparison.

Discussion and Conclusions

The results of table 1 show that even at moderate to low concentrations and at temperatures well below the boiling point, the common acids and alkalies show marked differences in their attack on wood.

Table 2.—BENDING STRENGTH OF REDWOOD CROSS SECTIONS AFTER EXPOSURE TO CHEMICAL SOLUTIONS AT 50° C. EXPRESSED AS PERCENTAGES OF BENDING STRENGTH OF CROSS SECTIONS EXPOSED TO WATER AT 50° C.

Chemical solution	Strength compared with specimens exposed to water		
	After 1 month Percent	After 3 months Percent	After 9 months Percent
Sodium carbonate 1.0 percent	47	44	32
Sodium carbonate 0.1 percent	65	67	43
Sodium bicarbonate 1.0 percent	81	76	55
Sodium bicarbonate 0.1 percent	92	88	80
Sodium hypochlorite 0.1 percent Cl_2	82	49	6
Sodium hypochlorite 0.01 percent Cl_2	102	105	58
Sodium sulfate 1.0 percent	106	98	93
Sodium sulfate 0.1 percent	113	106	99
Sodium bisulfite 0.1 percent	101	87	74
Sodium chloride 0.1 percent	106	83	110
Calcium sulfate 0.1 percent	98.1	109	102
Ferrous sulfate 0.1 percent	92	87	74

A 6 percent solution of sodium hydroxide was shown to be injurious to all species, even at room temperature. At 50° C. at 2 percent solution was definitely harmful. At the other extreme, cold 6 percent acetic acid showed little attack on any species. The softwoods showed consistently better resistance to the two mineral acids than did the hardwoods. There was much less difference between the hardwoods and softwoods in resistance to alkalies. The definitely greater effect of 2 percent nitric acid than 2 percent sulfuric is surprising in view of the fact that nitric acid tends to lose its oxidizing power at low cencentrations.

The superior acid resistance of conifers compared with hardwoods has been attributed to higher lignin and lower hemicellulose content. In view of the nature of these tests, the resistance of hardwood and softwood lignin to dilute acids, and the manner in which lignin is distributed in wood, one is led to suspect that the difference in lignin content is less important than the difference in the amount and nature of hemicellulose.

The data in table 1 show considerable agreement with laboratory studies of the rate of effect of various chemicals on the chemical composition of finely ground wood. The results are also more or less in line with practical experience in the use of these species exposed to these chemicals in plant operation.

Table 2 shows that, of the chemicals that may be present in cooling towers, chlorine is by far the most harmful. However, the concentrations of chlorine maintained for algae control are only about 1 percent of that of the weaker solution of sodium hypochlorite used in the tests. The data show that a temporary excess concentration of chlorine, which may result from a breakdown of controls, could cause considerable damage. Sodium carbonate at 0.1 percent was definitely harmful. Concentrations of approximately this value have been reported for samples of water taken from the basins of cooling towers. Where a local buildup of concentration results from evaporation, a fairly rapid deterioration of wood can be expected. Sodium chloride, sodium sulfate, and calcium sulfate showed no effect within the probable experimental error. On the other hand, sodium bisulfite and ferrous sulfate should be regarded with suspicion; whenever temporary conditions lead to abnormally high concentrations of these chemicals, corrective measures should be taken.

Some strength values in excess of 100 percent were obtained. While some chemicals might conceivably have a beneficial effect on the bending strength of wet cross sections, it is more likely that the results reflect the experimental error of the method used. The results for 10 weeks' exposure shown in table 1 are undoubtedly affected by some experimental error.

The results of these preliminary tests appear sufficiently promising to justify further work along this line. Certain modifications in the test method appear desirable. It would probably be advisable to use sets of more than five units and take alternate cross sections to form the control set and the set to be exposed to the chemical solution. It might be also desirable to get green boards, season them carefully, and then condition them to render them free of internal stresses. The obvious importance of a uniform direction of annual rings has been mentioned. Data obtained by such tests might be helpful in selecting a species for use in some new process.

Similarly, some idea of the permeability of different species by a given chemical might be obtained by exposing fairly large, end-coated pieces to the solution for varied periods and then analyzing successive layers of wood.

As select heartwood lumber of preferred species becomes more scarce, there will be increasing interest in the use of sapwood for less severe exposures. Here again, preliminary laboratory tests should be helpful.

Strength tests on large pieces are, of course, more nearly related to actual use conditions. Not only does the penetration of chemical take place largely through side grain as in use, but the

strength properties perpendicular to the grain are of greater significance. However, because of the variability of wood and the necessity of extensive replication of tests, such investigations tend to be very costly. In many cases only the less costly tests on small specimens would be feasible.

Because wood is an important material of construction in the chemical industry, further research on the deterioration of wood by chemicals is warranted. As a first step, test methods should be developed for obtaining the information needed for the most efficient use of wood in this field.

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Promotion and Research —Successful Marriage

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IF IT WERE POSSIBLE for a mythical man from Mars—with a pure, undefiled objective outlook on everything—to silently swoop down on this planet of ours and slip into a seat at any one of our industry conventions, or read some of our trade publications, I am sure he would be amused with the evangelistic fervor that the need for overall wood industry advertising and overall wood industry research is being so confidently expounded!

Ever since competition started to rear its ugly head, as our country moved from a wartime economy to a more normal era, there's been a hue and cry for universal panaceas to heal our hurts and solve our problems. The organization of the Marketing Committee of the Forest Products Research Society is another manifestation of this search for a cure if we listen to those who sincerely believe that centralization of promotional efforts is the "open sesame" to the winning back of lost markets . . . that all we need is a lot of advertising!

Just as the term, research, is a very complex one embodying such spheres as scientific research, product and application research, and manufacturing research so it is with marketing. It encompasses much more than advertising—a great deal more! Just to name a few phases of marketing we can start off with styling and design and then add the big subject of promotional packaging with its important companion of point of sale displays. This great big subject takes in methods of distribution, pricing and all the many ramifications of selling. Top this off with market research and you have by no means completed the highly interesting and intriguing studies that make up modern American marketing!

Sounds like marketing is far too big a subject for one committee, and it is! Our reason for giving members of the Society this peep-hole view is that if the formation of this committee is going to mean a marriage between Research and Marketing, we want you to know that the subject is fascinating entertaining—even voluptuous! The en-

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tire wood industry has been hag-ridden by too much strident whining for advertising. We want to live long and happily with you—to increase the services of the Society to its members. Successful marketing of the products of research means wider use of research and advancement of our whole industry.

So where do we start on this big subject of marketing? I am going to suggest that we start with a few phases of market research, as this seems appropriate as a jumping off place for an organization primarily interested in seeking facts and information.

Market research has been defined by Willard M. Fox in his book, "How to Use Market Research for Profit", as the 'art of accumulating, arranging, classifying, analyzing, interpreting, and organizing data from primary and derivative sources, both internal and external, such data being both quantitative and qualitative or descriptive, for administrative use in increasing net profit by increasing sales volume or decreasing sales and distribution costs, or both.'

I would like to shove our boat away from the nice quiet shore and start down the turbulent, dangerous river of marketing by referring to a remark of R. O. Eastman, the grand-daddy of market research, who constantly reiterated that "Markets are people".

Most of us who work in manufacturing plants forget, most of the time, that the things we make are for people. Even if we produce railroad ties or creosoted piles, our product is essentially for people. Now, it goes without saying that all people are not prospects for ties or poles. There's a limited number of people who buy these items.

We are right in qualifying Mr. Eastman's remarks by saying "Markets are *some* people". You don't sell $50,000 houses to $50 a week clerks, neither would you get very far marketing even deluxe styled chic sales' setups to the residents of Chicago's North Shore. Now, of course, both of these examples border on the ridiculous. Common-sense should be enough of a guide to solve this problem—but you would be surprised how little attention some of us pay to people when we design and manufacture a product; and get up a sales and advertising campaign to move it. Of course, this can't apply to you for your product was "consumer tested"!

Or perhaps you are one of those people who follows competition. One of your salesman comes in one day with the startling announcement that your competitor has something new on the market. So you set out to copy it. Maybe you make it a little better. Maybe you make it a little worse (so you can cut the price) but dollars to doughnuts if you are one of those who follow competitors you never stop to find out how big the market is or any other pertinent facts. (Why should I? Think I'm going to let that so-and-so get the jump on me?) So it goes! This method is all right if your competitor has made a market survey and knows what he is doing. It might even work out if he is a good guesser. But if he's neither, and just made up the item to work off some surplus raw stock, both of you are in for a lot of trouble.

People are markets, and they part with their hard-earned dollars when they want something you make more than they want their money. In order to sell more of a present product, the smart thing to do is to learn what kind of people buy your product and why they buy it. We hope that any study you make doesn't give you such shocking answers as "buy from habit" or "like your salesman" as the leading buying motives, for you are in for a worse shock if some competitor gets in with real "user reasons" and takes the business. It's always well to see that your advertising sells, and you are a very smart sales manager if you insist on the salesmen dropping an occasional remark on the quality of the product as well as taking the buyer to lunch!

Now I hope from the above that you don't think I am plugging the need for surveys—that all you need to do is get up a questionnaire and mail it to so many people, and then sit back and wait for the right answer. The majority of surveys that have come across my desk are lazy, expensive ways of getting any answer at all, let alone the right one. It was just a few months ago that we received a conglomerate of questions from one of our leading universities. This survey was intended to get our opinion as to the relative standing of lumber and competitive materials. They asked for opinion and also some definite percentages—figures that even our outstanding accounting department could not answer. We did not return the questionnaire. I've been wondering who did answer it, all the while hoping the client did not invest too much money making the survey or put too much stock in the results!

Now, you can learn a great deal from surveys. It doesn't take a million questionnaires to find the answer as size of a survey is not nearly so important as the quality of the sample. I have had two mail surveys which have checked out on a result basis—one made to mailing list of 5,000 and the other to only 1,000. One personal interview list of just thirty-five yielded some very important and valuable information. Let me reiterate, it is not how big, but how good your list is!

Then, of course, you've got to go down the line and believe the results even if the majority of the people answering the survey said, "bought it in spite of the advertising" and the whole ad campaign was your particular pet! That's the signal for changing the advertising right now so that it reflects the real reasons why people made their purchase. Big companies are constantly checking their selling appeals and their products. When public opinion says, "we hate their television commercials, but their blades are real good", the commercials are changed and sometimes the advertising agency.

One of the hardest things in the world to do is to be purely objective. Everyone has opinions, likes and dislikes—they come from our up-bringing, environment, friends and acquaintances. So when you have to make decisions, try to base them on the best facts obtainable. A true businessman should never kid himself—neither should he attempt to get opinions of subordinates for all they can do when placed on the "spot" is try to give the boss the right answer. It's really surprising to learn how well inattentive office boys and seemingly flightly stenographers have your thoughts catalogued.

Even though an organization tries desperately to be critical of its services and products, they never come up with the complete truth. Years ago, when I was writing advertising in a service department of a large metropolitan daily newspaper, buyers of a certain high grade men's furnishings store used to tell me constantly that their delivery service was faster and better when the store subscribed to the same common delivery service as their competitor! I've had the head of the shirt department extoll his values over those of all other stores when all he had to offer was nationally advertised shirts which could be purchased in another store just a block away at the same price.

Now, I am not going to say these men were untruthful. It was just natural for them to sell themselves on their store. I don't question at all that they really thought their delivery service was faster and better, that their shirts and stocks of other branded merchandise were better values. I cite this example to illustrate natural human weakness that blinds our eyes to our faults and builds up the qualities of our products and services in our own minds. Remember, you can be wrong! Berating salesmen, moaning about jobber methods and slip-shod dealers won't get you anywhere. A study of prospective buyers, some change in your sales approach or a different package may be the answer.

Just to cite a case in point, here's an experience we had in our retail yard organization several years ago when white painted Cape Code style houses were being built all over Chicago. Inasmuch as these new homeowners were buying fences, the management thought that it was a good bet to sell picket fences for historically white picket fences go perfectly with White Cape Cod houses.

Arrangements were made to buy a large quantity of gothic head western cedar and when several carloads arrived we started to advertise them in the usual way at so much a piece for the pickets. Nothing happened, so in the next ad we pointed out that the clear pickets were selling at a price that was cheaper than common lumber. As a result, we had a few sales but it was clearly apparent that if we depended on these sales tactics it would take us five years to move our stock.

Then the break came. A young man whose wife had set her heart on a picket fence got me on the 'phone and it was very apparent that he thought a picket fence cost a lot of money. He wanted to know how many pickets it took for fifty feet of fence. I told him the quantity and the price. When he learned that he needed a hundred lineal feet of 2x4's and they came to a relatively small amount, his enthusiasm picked up. He was really joyful when he learned that seven cedar posts and the nails brought the whole package up to $13.85, and I knew I had the answer. And I had! The next week we started advertising fifty foot fence "packages", sold our stock out and were able to bring in several more cars before the end of the season to set a real record.

Ever since that time in 1938, with the exception of the war years, when priorities knocked out fencing, we have advertised fence packages of all sorts with good results. That little woman who was determined to get her picket fence started something—package pricing—which is the commonplace thing in lumber yard advertising today, but was so unusual 16 years ago that trade paper editors picked it up as an unusual event!

The moral to that story is that the ordinary layman doesn't recognize a lumber value when he sees one. Homeowners in the Chicago market were buying lots of galvanized ornamental wire because it was sold on a lineal foot basis and they could figure the cost. If we hadn't hit on "packaging" our cedar picket fencing, it might also have slipped into the limbo of forgotten things and be listed as a market which was lost because we failed to do overall industry research or neglected to advertise generally that wood is good!

Marketing is a fascinating subject, and there are endless examples of little changes which have started people buying. If you'll pardon another reference to my own company, I would like to tell you a short story about "shorts" —a merchandising success which is being picked up by other lumber dealers throughout the country and promises to increase greatly wood utilization by providing a market for short lengths and low grades.

I don't have to tell you that "shorts" are a problem, but I am happy to say we can use that sentence in the past tense. The solution didn't come at once. We tried several ways of moving shorts—bundling them up as enough lumber to make a sand box, or to make a set of shelves—or as a hobby pack for making small things in the home work shop. That helped, but not very much. It also had its drawbacks for as soon as we tied a piece of twine around a bundle of short lumber it ceased to be the universal building material out of which thousands of things could be made, it became a sand box with a narrow market, narrowed further by seasonal demand.

We tried other methods including making up plans for furniture and hobby projects but still no go until we hit upon the device of the Economy Corner. This was simply a ten by ten bay in the main lumber shed of all of our retail yards. It was set apart with an attractive sign which read "Economy Corner—It's Smart to Be Thrifty—Serve Yourself and Save!" In this bay, we stood shorts up around the wall, priced them according to size and grade with merchandising prices—29c, 39c, 49c, etc. Our shorts began to move, yard foremen who were loathe to give up precious shed space were pleased—the "jag trade" was waiting on itself! Now we have to buy straight cars of "shorts" to keep our Economy Corners —filled up!

This idea is working and our growing "do-it-yourself" market likes it. It's a marketing success worth millions to the lumber industry. I don't want to rub it in but there's no need for research into what to do with shorts or some low grade which can be cut back to two foot and longer. Economy Corners in all 26,000 retail lumber dealer yards will please do-it-yourselfers; and even some contractors always find a piece or two they can use. No need to advertise that wood is better. What are people buying all the power tools for—to chew up iron? Just keep the Economy Corners filled with nice clean shorts with a price on every piece!

That's another fascinating marketing story. Perhaps all this great wood industry of our needs is more imagination, more work to find out what the public really wants!

Ever hear of window units—wood window units? Double hung styles, complete with weather-strip, hardware, spring balances and prefitted, rot-proof treated sash and frames? All you have to do is slip this window into the rough opening and nail on your trim. Ever hear of wood awning window units? Here's the perfect window for modern, contemporary design—the best kind of window for using insulating glass such as thermopane. Ever hear of slide-by wood window units, prefitted wood casements, roll-by wood picture windows as well as fixed glass wood picture windows?

I've put that in the form of questions for some of our loudest breast beaters who have seemed to have thrown the towel into the ring and hail the new champion—metal windows—don't seem to know that there's an amazing switch to wood windows throughout the country. New design and new styling has turned the trick, and at the National Association of Home Builders Show held last January in Chicago, the combined Wood Exhibit arranged under the leadership of Robert Morris, manager of Ponderosa Pine Woodwork, these new wood windows, as well as other wood products, stole the show.

Showmanship is an important part of marketing. The combined Wood Exhibit had interest, had color and sales appeal. Home builders responded to the individual exhibits where they could see and examine the design and style results of individual initiative. That's the American way of doing things. It simply can't be duplicated by overall industry research of overall industry advertising.

We hope in the Marketing Committee of the Forest Products Research Society to provide a means of exchange of ideas on all phases of marketing problems. We hope to provide a forum where good working ideas will be presented by members of the Society so that other members can hear true case histories of marketing successes. It is our aim to teach by example, to foster initiative and thinking on the part of all members, and last but not least, to make our programs interesting and stimulating.

If that can be done and if we can avoid trying to run other people's businesses, this marriage between Research and Marketing will not end in divorce. With forebearance and mutual respect, may these two segments of the Forest Products Research Society live happily ever after!

TECHNICAL SESSION VII—Fri., May 7, 1954, 1:30 P. M.

Subject: Wood Finishing

Chairman: W. E. Martin

Recorder: E. S. Johnson

Factors to Be Considered in Force Drying Wood Finishes

K. R. BROWN

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This paper discusses some of the formulations and characteristics of the various wood finishes that are force dried. It also points out the need for mutual consideration of all factors involved in the force drying of wood finishes by the finish suppliers, finishers and equipment engineers.

Introduction

THIS PAPER WILL NOT present any new technical data nor report on any recent developments. Rather it should be thought of as an assembly and contemplation of established facts. It is hoped that these considerations will serve to focus some thought and discussion on an area of wood finishing that poses some interesting problems to several groups of people associated with the wood industry.

The force drying of wood finishing materials embodies many problems that involve the producers of the finishes, the users of these materials, and the manufacturers of force drying equipment. It is felt that a better understanding of each other's enigmas will lead to a faster ultimate solution of the whole problem. The Forest Products Research Society is the one organization that brings these various groups together. It is our hope to bring out the important factors involved and thus create some real active discussion that will bring together these three groups: and out of these considerations may come some ideas and action that will be beneficial to all concerned.

Perhaps this paper will serve as a forerunner to further presentations before this organization of more specific, informative and beneficial studies on the various phases of the interesting and complex process of force drying wood finishes.

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The Substrata—Wood

It certainly will not be necessary to spend a great deal of time discussing the characteristics of wood before this organization. But to maintain continuity in our considerations, it will be well to review briefly those properties that relate to and affect its finishing.

Since one of the purposes of finishing wood is to enhance its beauty, stain is used to obtain a decorative and marketable color, and to accentuate the grain pattern. The porosity of the wood determines whether or not it is to be filled. Very porous woods such as mahogany, walnut, and oak require a highly-pigmented, heavy-bodied filling material. On the other hand, semi-porous woods such as maple, birch, gum, etc., or nonporous woods such as pine, and fir require less or no filling. The least porous woods are then usually stained by a highly colored pigmented stain which is wiped into the small pores. As its application would indicate, it is called a wiping stain and serves to both stain and fill the small pores of wood. With the very porous woods, the stain is usually applied separately and prior to filling. These stains are usually dyes dissolved in water—the water stains, or in solvent—the non-grain-raising stains. The filler, like the wiping stain, is wiped or padded into the pores.

As we all well know, wood is composed of fibrils. These will tend to stand on end as a result of the wiping action employed in the application of stain and filler. In order to eliminate these, a sanding sealer is applied. This sealer embrittles the fibers so that when sanded they are cut off, thus leaving a smooth foundation for the finishing coats. The finishing coats are applied according to the requirements of the finisher in sufficient thickness to provide the desired depth of appearance, satisfactory protection, and a film that can be subsequently rubbed and buffed where desired.

The property of wood that becomes the greatest single factor to be considerd in force drying finishes applied thereto is that of hygroscopicity. The hollow cell structure of wood allows it to absorb and release moisture rather readily. Any sudden change of moisture content usually has dire results on the wood or on structures made thereof. For this reason the relative humidity in ovens must be at a level to prevent sudden and severe loss of moisture from the wood. The high relative humidities thus required are in conflict with those factors contributing to the best drying of finishes. This property of wood not only requires humidity control but limits the temperatures at which force drying of wood can be carried out. Practical experience has shown that temperatures above 150°F. cause moisture change at a rate so rapid that checking of veneer, cracking of wood, delamination of plywood and loosening of glue joints can occur.

Drying Processes of Finishes

From the preceding discussion it can be seen that there are several types of finishing materials required to properly surface, decorate and protect wood. These types embody all of the three major processes that finishing materials undergo in drying.

1. **Evaporation of Solvent:** All of the conventional finishing materials are thinned to working consistency by suitable solvents. In order for a material to arrive at the dry state, this solvent must be removed from the film. In some cases, such as with lacquers or dye-type stains, this is the only process involved in drying. In other types of materials such as wiping stains, fillers and varnishes, solvent evaporation is the first stage of drying and must be followed by one or both of the other processes.

2. **Oxidation:** Many of the finishing materials in use today contain vegetable or animal fatty oils as the film-forming or "flexibilizing" ingre-

Table 1.—MODE OF DRYING PROCESS OF 13 FINISHING MATERIALS

	Evaporation	Oxidation	Polymerization
Water stains	X		
Non-grain raising stains	X		
Shading stains	X		
Fillers	X	X	X
Toners	X	X	X
Primers	X	X	X
Lacquer Sealers	X		
Varnish Sealers	X	X	X
Lacquer Top Coats	X		
Varnish Topcoats	X	X	X
Heat Converting Varnishes	X		X
Enamels (Varnish)	X	X	X
Enamels (Heat Converting)	X		X

dient. These substances dry by oxidation. That is, in their original state they are liquid or semi- solid in nature. In such state, satisfactory continuous films are not formed. They are converted to solid continuous films by reaction with oxygen from the air. Oleoresinous and alkyd type varnishes must utilize this drying process since they include oils in combination with resinous materials. Fillers, being essentially pigmented oils, also require the oxidizing process.

3. Polymerization: This term refers to the chemical reactions which tie together many molecular groupings to form long chains of the chemical building blocks. In the "mono" form a chemical is liquid or soft compared to the "poly" form. In other words, as the molecular weight (or the number of molecular groupings tied together) increases, the harder, more insoluble, more chemically resistant a compound becomes. This process takes place only after the molecules are sufficiently activated. They can be thermally excited by heating or they can be chemically turbulated by catalysts. Obviously, and such is the case with wood finishes of the strictly polymerizing type, molecular agitation can be accomplished by a combination of both means. The heat-converting varnishes are of this type. Polymerization is also involved with oxidizing type materials since oxygen serves to cross link oil molecules.

Table 1 will show how most of the wood finishing materials employ combinations of these three drying processes.

Requirements of Force Drying Equipment

In light of what was discussed above relative to the various physical and chemical forces that are involved in the drying of wood finishing materials, it can be seen that there are three fundamental requirements of force drying equipment—(1) evaporation of solvent, (2) provision of oxygen, (3) thermal molecular excitation. Because the substrata (wood) is hygroscopic and subject to effects of moisture change, a fourth requirement is expected of this equipment—to provide controlled humidity.

Evaporation of Solvent

From Table 1 it can be seen that all of the conventional finishing materials must lose their solvent as the first step in drying. This is accomplished by the heat provided in the oven and by air movement. The heat provides the kinetic energy necessary to drive the solvent from the film. The air movement carries the vapor away from the area immediately adjacent to the film surface so that the evaporation process can continue at a satisfactory rate. If the vapor was not carried away some of the molecules could condense and again become entangled in the film. This would lower the net effective evaporation rate.

Another consideration to be made in regard to the effect of heat is that as soon as some solvent evaporation takes place a cooling effect results which tends to lower the temperature level. This means that a certain thermal input is necessary just to maintain the dynamic balance of the system. To increase the evaporation rate the temperature must be increased accordingly.

From a practical point of view, it would seem that the quicker the solvent can be driven off the faster will be the total finishing schedule. This is true, but there are limiting factors introduced by performance characteristics of the material. Time often must be sacrificed to obtain proper performance. Solvent must be lost at a rate that will reconcile these factors.

Sufficient time must be allowed, for instance, for the material to flow out properly before too much solvent is lost. If this time is not allowed the film will show "orange peel".

Too rapid initial evaporation, whether from too much heat or air movement, might cause excessive solvent loss from the surface of the film, resulting in "casehardening". Then as the solvent beneath the surface tries to escape through the hardened surface it would blow the surface into small bubbles or blisters.

Also, if dynamic balance is not maintained between heat input and rate of evaporation, excessive evaporation of solvent from air flow might reduce the temperature sufficiently to condense moisture on the wet finish surface. Water would "kick out" the solids from colloidal solution causing bloom, or blushing evidenced by areas of dullness and whitening of the film. In most cases subsequent heating is not sufficient to remove this defect.

Therefore, the proper rate of evaporation is determined by the performance of the particular material being dried. This is sometimes done by a suitable gradual increase of temperature or air movement in the oven. As a matter of fact, in the majority of cases a "flash off" time at room temperature is necessary before introducing into the force drying equipment.

Provision of Oxygen

The provision of oxygen, of course, is done by the introduction into and movement of air through the drying oven. From the chemical point of view, there is no maximum limit on oxygen provision. The film will take up the amount it requires and no more. There is a definite limit on the minimum side. A little stoichiometry will determine this for any given finish. The amount of air necessary for physical reasons, however, is usually several times that required chemically.

If an insufficient amount of oxygen is provided, it means improper drying of the finish. In the case of fillers or wiping stains, improper drying could lead to poor wiping, open pores and filler blushing. With varnish sealers or primers, poor sanding would be encountered and consequent unsatisfactory surfacing and adhesion could result. Improperly dried topcoats would show poor print resistance, unsatisfactory water and chemical resistance, softening back during rubbing and buffing; and many and varied surface defects.

Thermal Molecular Excitation

The polymerizing reactions involved in the curing of thermal setting and drying of other types of varnishes are dependant on the increased movement of molecules. Simply by the law of probability separate molecules will contact each other more often in a given time if the frequency of their vibration and orbit of activity are increased. Heat is the most common method of exciting molecules. The heat-converting resinous materials are so formulated that on molecular excitation the smaller chemical units unite to form larger molecular units that make up the film forming polymers. The only factor to be considered here is that the force-drying equipment provides the temperature and time schedules that the formulator has found is necessary for the particular coating involved. Figure 1 shows a typical time and temperature study of a conventional thermal-setting coating. Temperature ladders are run to determine such curves at several temperature levels. The point at which the proper hardness is obtained determines the recommended temperature-time schedule. The proper hardness rating is that point at which satisfactory chemical resistance is attained as well as the actual hardness necessary for proper rubbing and packing performance.

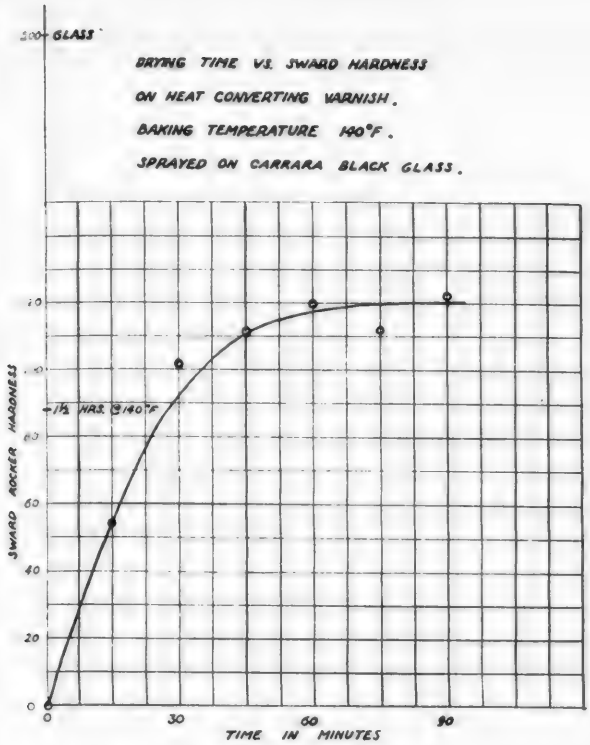

Figure 1.—Effect of time of varnish curing (left).

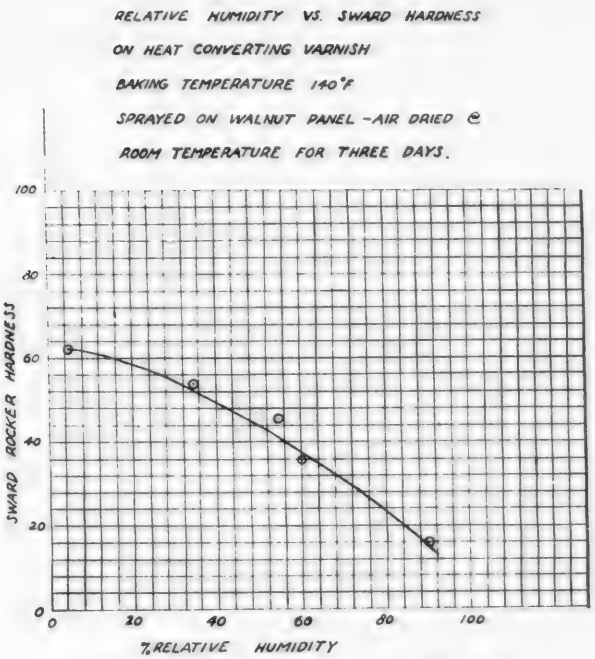
RELATIVE HUMIDITY VS. SWARD HARDNESS
ON HEAT CONVERTING VARNISH
BAKING TEMPERATURE 140°F
SPRAYED ON WALNUT PANEL - AIR DRIED @
ROOM TEMPERATURE FOR THREE DAYS.
SWARD ROCKER HARDNESS
% RELATIVE HUMIDITY

Figure 2.—Effect of humidity on varnish curing.

Table 2 shows typical equivalent temperature-time schedule comparisons as developed from the type of data described above.

Needless to say, insufficient heat would result in undercuring and the same general film failures that improper drying of oxidizing finishes would exhibit.

Humidity Control

The need for proper humidity provision to maintain the optimum moisture content in the wood has been pointed out above. It is believed most finishers prefer to maintain wood moisture contents at 5 to 7 percent. Table 3 shows the relative humidity values necessary at various temperature levels to maintain a 7 percent moisture content. Table 4 gives the data at 5 percent.

Above it was also stated that in general any humidity is a deterrent to finish drying. This is true since moisture vapor in the atmosphere retards evaporation of solvent. There is no real agreement as to the correct theory on this phenomena. Excessive humidity is also a source of trouble due to its possible condensation into the film causing poor drying, blushing, blooming, frosting, or low gloss.

In the polymerization process, certain voltatile vapors, not solvents, are released by the chemical reaction. High humidity retards the release of these vapors. Figures 2 and 3 show the effect of humidity on curing converting varnish. Figure 2 shows the curve resulting from plotting hardness against humidity at a fixed schedule of 140°F. for 1½ hours on walnut panels at 7 percent moisture content.

Figure 3 is the same except that glass panels were used in order to obtain direct hardness readings free from surface variations in the substrata.

Hardness was determined by the Sward Hardness Rocker, an instrument that works on the principal that soft surfaces will provide more resistance than harder ones to swinging of the chrome-plated brass swings. The values are simply the number of swings made through an arc of 20° as measured by tube style levels.

The tables show that as humidity is increased, the film hardness decreases. At about 60 percent the hardness drops off sharply indicating practically no cure at higher humidity levels.

Table 2.—EQUIVALENT BAKING SCHEDULES FOR CONVENTIONAL THERMAL SETTING VARNISHES

Schedule A[1]	Schedule B[2]	Schedule C[3]
1½ hours at 140°F.	1 hour at 140°F.	¾ hours at 140°F.
2¼ hours at 130°F.	1½ hours at 130°F.	1 hours at 130°F.
3 hours at 120°F.	2 hours at 120°F.	1½ hours at 120°F.
16 hours at 100°F.	16 hours at 100°F.	16 hours at 100°F.

[1] For finishes to be rubbed, buffed or packed one hour after removal from oven.
[2] For finishes to be rubbed or buffed 18 to 24 hours after removal from oven.
[3] For finishes to be packed unrubbed 18 to 24 hours after removal from oven.

Table 3.—RELATIVE HUMIDITY-TEMPERATURE RELATIONS TO MAINTAIN 7 PERCENT EQUILIBRIUM MOISTURE CONTENT

°F. Dry-bulb	°F. Wet-bulb depression	Relative humidity percent
100	21	39
110	22	41
120	23	42
130	24	45
140	25	47
150	25	49

Table 4.—RELATIVE HUMIDITY-TEMPERATURE RELATIONS TO MAINTAIN 5 PERCENT EQUILIBRIUM MOISTURE CONTENT

°F. Dry-bulb	°F. Wet-bulb depression	Relative humidity percent
100	28	24
110	29	27
120	32	28
130	34	29
140	34	32
150	36	33

Desirable Equipment Design Characteristics

There will be no attempt made here to discuss in detail oven and conveyor design. This should be left to those people who are informed in that field. In view of the demands made on such equipment by the fundamental chemical and physical properties of finishing materials, it would be well to discuss the very basic desirable design features from the finish producers' point of view. These are discussed under the three functions of force drying equipment: (1) temperature and time schedule, (2) air movement, and (3) humidity control.

Temperature-Time Schedule

The major concern under this function is that the temperature cycle be satisfactory. In general the temperature

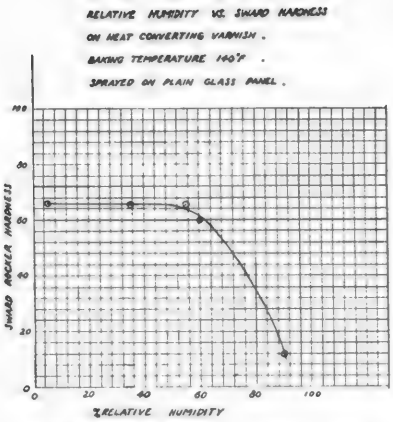

Figure 3.—Force-drying schedule study.

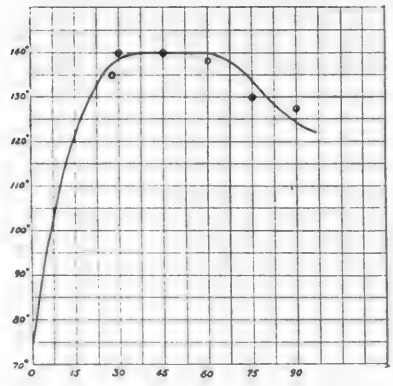

Figure 4.—Improper baking-temperature curve.

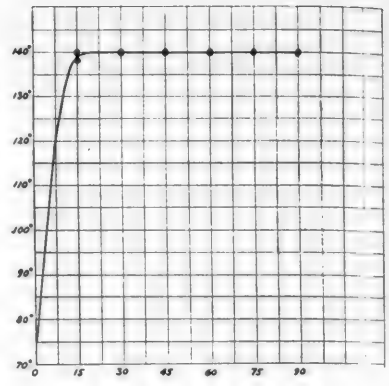

Figure 5.—Ideal baking-temperature curve.

should rise gradually, reach the specified level and hold at that value for the proper time. In some cases ovens are designed on the basis of finishing material formulations, but in the majority of the cases the opposite is true. Regardless of which is the case, the proper temperature cycle must be provided. Figure 4 shows the type of temperature cycle that is often encountered. Obviously this does not give the optimum temperature throughout the entire length of the cycle. Figure 5 shows the desirable curve. The sliding temperature curve of Figure 4 is often encountered in batch-type kilns where the heat is turned on full late in the afternoon, then turned off at quitting time and allowed to drift during the night. The same type of thing is encountered in conveyor ovens, probably because of improper design or inconsistent control.

Also of importance to proper drying of the finish is the distribution of heat. There should be no areas in the oven where heat is not carried. Many times the bottom of the tunnel is not sufficiently heated. How the heat is introduced is a problem for the oven engineers but in their designs they should take into consideration the type, size, and shape of pieces being finished. This may make some differences in the manner that heat distribution is provided. It is also important that the kiln and conveyor designers recognize the type of coating materials to be used and are familiar with their properties. Complete knowledge of these facts will aid greatly in providing the correct flash-off time, upheat rates and temperature and conveyor speeds (or batch kiln capacities).

In conveyor systems the time factor is controlled by the speed of movement through the oven. The conveyor engineers are therefore to be consulted as an integral part of the team that must cooperate in this endeavor.

Air Movement

Direction of Flow: The flow of air through a conveyorized oven or tunnel type kiln should preferably be counter to the direction of movement of the finished pieces. In this way air relatively free from vapor sweeps across the dried film first and carries vapor it picks up in its travel through the oven toward the front end where vapor concentration is necessarily high. If the air movement is in the direction of flow of pieces, it would carry vapor-laden air over the dried film, thus tending to reduce maximum drying efficiency or resoftening of the finish.

Distribution of Air: The mere movement of air is not the only consideration to be made. As pointed out above, the heat should be evenly distributed, so the air movement should be such that there is hot air moving throughout the entire cross section of the oven.

Amount of Air Flow: The amount of air introduced into the oven is limited on the maximum side by economy and on minimum by the lower explosive limit. The National Board of Fire Underwriters require not less than 10,000 cubic feet of fresh air per gallon of solvent to be evaporated.

Ratio of Fresh Air: Another consideration of the air flow problem is the ratio of recirculated air to fresh air. A generally accepted ratio is three parts of recirculated air to one of fresh. No formula exists to logically determine this ratio. Consultation between finish supplier, finisher and equipment manufacturer would be in order on this point.

Humidity

The limiting factor of humidity has already been discussed. The main things to be kept in mind are: (1) that proper engineering has been applied to provide proper moisture contents and method to accurately control that content, and (2) that good maintenance is provided to insure consistent humidity control.

A factor of equal importance to that of engineering to obtain satisfactory levels and distribution of heat, air and humidity is the provision of high-quality instrumentation. Recording thermometers, manometers and hygrometers properly placed are highly desirable. The cost of installation and maintenance of such equipment will surely pay for itself in reduced finishing troubles. The assurance of properly operating equipment adds to the efficiency of plant operation and finishing quality control.

Further Considerations

There are many questions that cogitating on this subject should bring forth. There is need for serious study on certain phases of the general problem.

Someone, for example, should develop a physical law to explain the phenomena involved in the retarded evaporation of solvents by high humidities.

All the factors should be considered to arrive at some kind of rule regarding the length of flash-off time necessary for particular finishes.

A formula should be developed to determine the amount of fresh air necessary to dry a finish and its correct ratio to recirculated air.

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Natural Wood Finishes For Exteriors of Houses

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If the ever popular natural finishes for wood siding are to be used with satisfaction attention must be given to the rather exacting conditions for their maintenance. Such finishes are of two general types—penetrating or intrasurface coatings and surface coatings. Both must be carefully selected and applied and renewed oftener than other types of exterior finishes.

NATURAL FINISHES for wood siding on houses have become increasingly popular in the past 10 years. They are most frequently used on redwood and western redcedar, woods that have a natural reddish-brown color. To a lesser extent they are also used on lighter colored woods such as cypress, pine, and Douglas-fir.

Many natural finishes are clear or transparent, but some are pigmented slightly; enough pigment is added to impart some color to the wood but not enough to hide or mask the grain of the wood. They are not made with as much pigment as shingle stains, for example.

Natural finishes can give satisfactory service, provided a suitable finish is selected and properly applied and maintained. But natural finishes in general are much less durable than good quality house paint and must be renewed much more frequently. House paint should serve at least 4 years before needing renewal, and a 6-year interval between repaint jobs is better yet. By contrast, most natural finishes need to be renewed once a year; on those parts of a house fully exposed to sun, wind, and rain, more frequent renewal may be necessary.

As a rule, natural finishes do not protect wood against weathering as well as good quality paints do. The house owner who plans to use a natural finish should select siding of one of the woods that holds finish well and has little tendency to warp, split, and pull at fastenings. Woods combining these requirements in a high degree are cypress, redwood, and western redcedar. Northern white pine, sugar pine, and western white pine are very nearly as good for the purpose.

The lowest courses of siding on the south side of the house are, as a rule, most severely exposed, and natural finish there needs most frequent renewal. Trees or neighboring houses may reduce the severity of exposure, but normally, both natural finishes and paints fail first on the south side of the house. Exposure on the east and west sides is about equal and not nearly as severe as on the south side; that on the north side is the least severe. Siding immediately under an overhang is partly protected from the elements, and natural finish on such areas can go longest between renewals.

When smoothly surfaced wood, such as the planed face of siding, is allowed to weather naturally (without protection from finish), its appearance changes during the first few years and thereafter changes very little. The natural reddish-brown color of such woods as redwood and western redcedar disappears in 3 to 6 months. The substances that give these woods their color are soluble in water, and rainwater leaches them from the surface. Woods of lighter color, such as cypress and the pines, may first become brown from the action of the sun, but they, like all our woods, eventually become gray in all areas where there is some rainfall. Some woods become a lustrous, silvery gray; others become a dull, darker gray.

Weathering also roughens smooth wood surfaces. It causes grain raising, checking, and cracking, and later may cause boards to warp, split, cup, and pull at their fastenings.

There is no way of keeping wood very long with exactly the color and natural sheen with which it comes from the lumber yard. All finishes penetrate into the wood to some extent, displacing air from the wood cells and thereby deepening the color of the wood. This is true even though the finish is colorless. For example, water darkens wood.

Whether wood is left unfinished or given a clear finish, sunlight gradually darkens most woods by changing yellows and reds toward brown. Clear or transparent finishes do not prevent this color change because they transmit rather than reflect sunlight. Finally, most clear finishes themselves darken with age, adding to the overall darkening of the wood.

Natural finishes that impart gloss or luster to wood when originally applied should ordinarily be renewed when the finish becomes as dull as unfinished wood. If the wood begins to turn gray, however, the finish should be renewed immediately. In no case should renewal be delayed until the wood becomes roughened or cupped, because then the wood must be scraped and sandpapered to restore a smooth, bright surface.

Natural finishes may be classified into two types: the penetrating or "intrasurface" coatings, and the surface coatings. The penetrating coatings soak into the wood and do not leave a continuous film of appreciable thickness on the surface. The oil finishes, the wood sealer finishes, and the water-repellent preservative finishes are of this type. They may be clear or slightly pigmented. Varnish finishes are surface coatings, and they usually do not contain pigment.

Unfortunately, the trade names of commercial products do not necessarily indicate the type to which they belong. For example, a material sold as a "log cabin oil" or "log cabin finish" may be an oil finish, a sealer finish, or a varnish finish. The user often has no way of knowing what type of finish he has until he applies it.

Some manufacturers now make a colored base coat and a topcoat of the surface-coating type to be applied over it. Others sell a clear finish of the surface-coating type in combination with a tube of color-in-oil that may

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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be added if the used wishes color in his finish.

Penetrating Finishes

Oil Finish: The oldest and simplest of the penetrating finishes is linseed oil, either raw or boiled. Boiled linseed oil contains driers; raw linseed oil does not. Either may be used if applied in warm, dry weather, but during cool or damp weather it is better to use boiled oil. Turpentine or mineral spirits is sometimes added to the oil, and it helps to avoid leaving any excess on the surface. Not more than ½ gallon of thinner should be added to a gallon of oil; more than that amount seriously reduces the protection provided the wood.

Because the oil finish penetrates completely into wood, it imparts very little luster or gloss to the surface of the wood. It also darkens the color of the wood more than other natural finishes. Moreover, the oil finish continues to darken with age more than other natural finishes do.

Bodied oils do not penetrate the wood so deeply as raw or boiled oils do and therefore do not darken the wood so much. They are made by treating the oils chemically or heating them for some time to increase their viscosity. (Boiled oils are heated moderately and are of essentially the same viscosity as raw oils.) Bodied oils must be thinned with paint thinner to a viscosity suitable for application. Most trade-brand oil finishes are of this type. The bodied oils approach the properties of wood sealers as the degree of bodying is increased.

The oil finishes may be applied by brushing, spraying, or mopping. For new wood two generous applications are needed. If after the second application of oil there are any glossy spots where excess oil stands on the surface, it should be wiped off before it dries. Surface coatings of linseed oil are unsatisfactory because they are too soft, tend to hold dirt, and become mildewed easily. They are also inclined to run and to wrinkle.

In renewing an oil finish after it shows signs of wear, one application should be sufficient. Again, any oil not drawn into the wood should be wiped off.

The oil finishes, like the other natural finishes of the penetrating type, may be improved markedly by adding a small amount of pigment. Some trade-brand oil finishes on the market contain pigment. Those that do not can be pigmented by adding a small amount of the color-in-oil sold at paint stores for tinting paints. One-half pint or less of a mixture of equal amounts of raw and burnt sienna-in-oils added to a gallon gives the oil finish a color resembling that of the heartwood of redwood or redcedar. The color-in-oils should first be stirred thoroughly with a little of the oil finish until free of lumps, then stirred smoothly into the rest of the oil.

The addition of pigment usually adds materially to the durability of oil finishes. It also changes the pale color of the sapwood of redwood and redcedar to resemble the heartwood and gives a richer color to such woods as pine, cypress, and Douglas-fir. By masking the gradual darkening of the wood itself, the pigment permits better maintenance of color.

The oil finishes serve best in dry regions, such as southern Arizona, where there are no prolonged periods of dampness. In areas where dampness may prevail for some time, the oil finishes may be attacked by fungi, commonly called mildew, that cause dark brown to black discoloration. Mildew can be prevented by adding suitable preservatives to the oil finish. Some, but not all, of the trade-brand oil finishes contain preservatives, but only those with the kind and amount stated on the label may be relied upon. The mere statement that the finish itself is a preservative is meaningless because there is no general agreement on the meaning of the word "preservative."

If linseed oil or a commercial oil that does not contain preservative is used, there are two ways to protect the finish from fungi. One way is to add a concentrated solution of pentachlorophenol or other chlorinated phenol to the oil instead of adding turpentine or paint thinner. These solutions are sold at lumber yards for preserving wood. If the directions on the preservative say that it is to be mixed with three times its volume of fuel oil for use as a wood preservative, it may be mixed with three times its volume of oil for an oil finish.

The other way to protect the finish is to buy one of the paintable water-repellent preservatives now sold at many lumber yards and some paint stores. It should be applied to the wood before the oil finish is put on. In most cases the finish can be renewed with oil alone, for the treatment with water-repellent preservative need not be repeated for 3 or 4 years.

Wood Sealer Finish: Another penetrating finish is the wood sealer finish. Wood sealers, like varnishes, are made of resin, drying oils, thinners and driers. Both are made, as a rule, by cooking the resin and drying oils together in suitable proportions. In making a sealer, however, the mixture is cooked longer to obtain greater body and to improve sealing effectiveness.

Wood sealer finish, like the oil finish, sinks into the wood cells nearest the surface without forming a continuous coating of appreciable thickness over it. In fact, any sealer left on the surface of the wood should be wiped off before it becomes too dry to wipe. Sealers do not penetrate wood so deeply as oils do and therefore do not darken the wood so much. For the same reason they impart more luster or glossiness to the surface of the wood than oils do. If excess sealer remains on the wood, it forms a glossy, varnish like finish.

Many wood sealer finishes are sold at paint stores under trade-brand names. Unfortunately, the names and the directions for use often fail to indicate clearly whether they are intended to be wood sealers or varnishes. The importance of wiping off any sealer that is not absorbed by the surface is seldom properly emphasized. As a result the uninformed user may start out with a sealer finish and end up, after one or two renewals, with a varnish-like finish that is less durable than the true sealer finish.

Although most wood sealers are more resistant to mildew than the oils, they are less resistant than good house paints. Wherever there may be periods of lingering dampness, therefore, it is advisable to have a preservative in the sealer finish. Some commercial sealers, like the oils, already contain preservative. Those that do not can be fortified by either of the two methods suggested for oil finishes.

Some commercial wood sealers contain pigments for the same desirable purposes already described for oil finishes. Pigments may be added to clear sealers by the methods suggested for pigmenting oil finishes.

Water-repellent Preservative Finish: Probably the most satisfactory natural finish of the penetrating type is the water-repellent preservative finish. A water-repellent preservative is a solution of hydrocarbon wax, such as paraffin, resin, or resin and nonvolatile oil, and a preservative, such as a chlorinated phenol, in mineral spirits or other volatile solvents. It penetrates and continues for some time to spread into wood. The wax and possibly the resin and oil make the surface of the wood repellent to water, and the preservative adds mildew and decay resistance to the wood.

Paintable water-repellent preservatives have been used for more than 15 years to treat window sash before they are painted. Only in the past few years, however, have these preservatives been used as a natural finish, and for this purpose they are usually pigmented with a small amount of reddish-brown iron oxide. The pigmented water-repellent preservatives sold as natural finishes commonly contain more wax than the type used to treat sash, and, as a result, they are not paintable

One application of pigmented water-repellent preservative is usually sufficient on new wood, although two applications provide somewhat more protection. On wood that is badly weathered or discolored, two applications should always be used. Because of its penetrating property, no excess is likely to remain on the surface of the wood even after two applications.

Surface Coatings

Varnish Finish: Unlike the penetrating finishes, varnish covers the wood with a coating of appreciable thickness. With most varnishes, the coating is highly glossy, but they may be made to have less gloss or even to be dull or flat. At first varnish may not darken the wood much more than a sealer does, but in time there is likely to be more darkening caused by changes in the varnish itself.

Ideally, the best varnish to use on large areas is one that disintegrates by a very fine crazing followed by fine crumbling, as the old fossil-resin varnishes used to do and some ester-gum varnishes still do. The newer synthetic-resin varnishes may remain free from crazing and maintain gloss for a relatively long time, but in the end they tend to crack, curl, and scale badly. In practice, however, a house owner has no way to tell one type of varnish from another. Labels seldom tell what the varnish contains, and terms like "spar varnish" and "marine spar varnish" mean different things to different manufacturers.

Nearly every paint store sells spar varnish of some kind. Marine spar varnish, intended for use on boats, is apt to be somewhat more durable than ordinary spar varnish. Varnish is best applied by brushing, and at least three coats are needed for new wood. The first coat of varnish may be thinned moderately (up to 1 pint per gallon) with turpentine or other paint thinner. Succeeding coats should not be thinned; they are not expected to penetrate the wood and, of course, none of the varnish should be wiped off the surface.

Shellac should not be used for the first coat on exterior wood surfaces, even over the knots of knotty pine. It is not resistant to water and, as a result, may in time look unsightly, even though several coats of varnish are applied over it.

Where there is dampness at times, varnish finishes need protection against mildew just as sealer and oil finishes do. Unless varnish already contains a preservative, it is advisable to apply a paintable water-repellent preservative to the wood before applying any varnish. It is not practicable to add a concentrated preservative to a varnish nor is it good practice to add pigments to varnish. If color is desired, it is best to apply a pigmented oil stain to the wood first, then to varnish over it.

For renewal, one coat of varnish is usually sufficient. Unfortunately, it is difficult, if not impossible, to limit recoating to the more exposed portions of a side wall where renewal is needed. The freshly applied varnish does not match the older varnish in gloss and color, so protected areas must usually be recoated even though they do not need renewal. After two or three renewals, the varnish coating on these areas becomes too thick and begins to crack and scale badly. It then becomes necessary to remove all of the old varnish with varnish remover before the finish can be properly restored—an expensive and laborious job.

Changing from Natural to Paint Finish

Many house owners who originally apply a natural finish on their house later decide to change to house paint. They may be disappointed with the natural finish or unwilling to renew such a finish as often as is necessary.

Since no natural finish serves ideally as a prime-coat for paint, certain precautions must be taken to assure satisfactory results. Oil and sealer finish may be painted over with less risk than other natural finishes. If these finishes are entirely within the wood, paint can be safely applied without removing the natural finish. Even then it is wise to let the last coat of natural finish weather for a year before applying paint. If after that time some of the protected areas remain glossy, the surface should be sandpapered to remove the glossy material. Then a priming paint suitable for use under the paint chosen for finish coats should be applied just as it would be on new wood.

A natural finish of the surface-coating type must be removed completely from the wood before paint may be safely applied. This may best be done with a varnish remover. Special attention should be given to removing the finish from the more protected surfaces where it will usually be in best condition. All of the surface should be sandpapered lightly, then the priming paint should be applied as it would be on a new house. Suitable topcoats can then be applied as usual.

The amount of wax in the pigmented water-repellent preservatives used as natural finishes makes this type of finish most difficult to paint over. The wax interferes with the drying and the adhesion of paint coatings. Therefore, several years should elapse between the last application of such a finish and the first application of paint. Before paint is applied, the surface should be treated with varnish remover, then with paint thinner or soap and water to remove most of the wax. Special attention should be given to removal of such finish from the more sheltered areas. Unless such precaution is taken in preparing the surface, shingle stain might better be applied over this type of natural finish.

Testing of Finishing Materials For Woodwork

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The testing of finishing materials for use on woodwork must rely on a combination of empirical and standardized methods.

The final evaluation of any material is by necessity a combination of the operators' opinions and the results obtained with standardized equipment.

The testing of finishing materials, to be used on Singer cabinetwork, is conducted by chemists and engineers familiar with the relationship existing between laboratory analysis and production application.

The paper is a summary of the tests conducted at South Bend.

THE TESTS USED by The Singer Manufacturing Company on finishing materials for cabinetwork are numerous and varied.

Whenever standardized tests, such as those designated by The American Society for Testing Materials, can be applied, they are used. For the most part, however, the testing schedule has been devised as a result of problems occurring in production, in transportation and in the hands of the consumer.

The laboratories exercise utmost care in testing and approving a finishing material for production use, since materials approved for production use are applied to cabinets manufactured in several factories located in foreign countries as well as plants in the United States. Cabinetwork, therefore, must meet the requirements necessary to withstand the subzero temperatures of the Arctic as well as the hot, humid conditions at the equator.

When a sample of a new material is submitted for tests, such as one from a foreign plant, or a newly developed material from a domestic supplier, it is subjected to extensive testing. Routine samples of approved materials, on the other hand, are given only a few selective tests.

In the concluding section of this paper, each finishing material, such as stains, fillers, etc., is listed with the corresponding tests performed upon it.

The following are the tests that are performed on finishing materials submitted to South Bend:

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Viscosity Measurement—Ford Cup

The reporting of the viscosities for materials tested at South Bend are always made with respect to seconds in the Ford 4 Cup. The viscosities of materials supplied to foreign countries are defined in centipoises. This eliminates any possible confusion as a poise is an absolute unit with universal definition. In all other systems, such as the Ford 4 Cup, Saybolt Universal Viscosimeter etc., the instrument must be defined, as the interval measured by one means is never the same as that measured by another.

In recording viscosities, temperature is an important variable. In making readings with the Ford 4 Cup, two specimens of a sample are required. One determination is made in a room where the temperature is higher than the required 20° C., and one determination in a room where the temperature is lower than 20° C. The final value for the viscosity of the material at 20° C. is made by interpolation. Two readings are necessary, the lower being close to the 20° C., for the reason that the change in viscosity between two temperatures is not linear and must be calculated. Determinations are not made at 20° C. because of the difficulty of conducting the test in an environment that is at a constant temperature of 20° C.

The Ford Cup, Figure 1, is a cylindrical, chromium-plated brass cup, the bottom of which tapers to a small cylindrical outlet. A trough around the upper edge of the cup holds excess material poured into the cup when the test is being prepared.

The operator of the test fills the cup, supported in a ring stand, with the sample of material being tested, while he keeps the hole in the bottom of the cup closed. A container is placed under the cup to catch the material which runs out during the test. The operator unstops the hole in the bottom of the cup and begins the operation of a stop watch simultaneously. He stops the watch when the stream of liquid from the cup breaks. The time interval, together with a reading of the temperature of the material collected under the cup, gives the value of the viscosity in seconds. The usual range of viscosities for lacquers to be applied by cold spraying is from 23 to 27 seconds.

Viscosity Measurement—Zahn Cup

Changes in temperature affect the viscosity of finishing materials, heat thinning them, cold making them thicker. In addition, the viscosity of a finishing material may be changed during specific production conditions by the addition or evaporation of solvents.

Because of these conditions, repeated tests can be made in production with the GE Zahn G2 Cup Viscosimeter to maintain control over their working quality.

The bullet-shaped Zahn Cup, Figure 2, is made of chrominum-plated steel and has a small hole in its rounded lower end. It is suspended by

Figure 1.—Operator times flow of sample running from hole in bottom of Ford 4 cup, stops watch when stream breaks, reports viscosity in terms of seconds.

Figure 2.—The Zahn G2 cup maintains control of viscosity during production.

a looped wire handle to which a thermometer is attached. The operator holds the Zahn Cup by a loose wire ring passed through the upper end of the handle and the cup hangs vertically.

He lowers the cup into the liquid being tested and leaves it there long enough for the thermometer to adjust to the temperature of the liquid, geting a simultaneous temperature reading of the test sample. Then he raises the cup out of the liquid carefully and, with a stop watch, measures the time required for the material to drain from the cup.

The reading on the watch is converted by means of a table to give the value of the viscosity of the sample in centipoises.

Refractive Index

The refractive index of a lacquer or varnish is the expression of a mathematical ratio. It is based on the relationship of two angles, one between the surface of a sample and a ray of light striking it, and the other between a perpendicular to the surface and the degree to which the ray of light is bent, or refracted, when it passes into the material.

Rays of light are always bent when they pass from one transparent substance into another of different refractive index. The amount of bending is always the same for a given material at one temperature, and the test is made to record this identifying characteristic.

The operator uses an Abbé–Zeiss Refractometer, Figure 3, recommended by ASTM, to measure refractive index. He places a drop of the liquid sample between faces of a pair of prisms in the apparatus. Light from a focusing lamp is reflected by a mirror into the first prism, then through the sample material into the second prism; from there, the light passes through a second pair of prisms, compensating for color changes in the light, and through a telescope eyepiece to the eye of the operator. Because heat affects refractive index, the temperature of the sample is controlled by water flowing through

Figure 3.—Light passing through the prism system and a droplet of the sample in the refractometer is focused by eyepiece to get a sharp image. Movable arm with eyepiece at left positions the light in the instrument and gives the value of the refractive index on arc-shaped scale.

the instrument around the first pair of prisms to an outlet.

The operator looks through the eyepiece at the image which appears as a light upper field and a dark lower field. He makes any necessary adjustments for color change by moving a collar below the eyepiece, then moves an arm on the side of the prism assembly to bring the edge of the dark field to the intersection of diagonally-mounted cross hairs. An arc-shaped scale above the adjustment arm gives the refractive index of the sample at the temperature indicated by a thermometer set into the instrument.

In reporting results of the test, the amount of color correction is noted, and a calculation is made from the reading on the refractive index scale and the thermometer, to give the refractive index of the sample at standard temperature.

Figure 4.—The position of the needle on the scale in the center of the larger box gives a direct reading of the glass value of a dried film of a sample coating on the glass slide placed on the unit at right.

Gloss Value

Gloss value is a measure of the reflective power of the film of a coating material. The beauty of cabinet woods is enhanced by the use of clear, smooth finishes which give depth and clarity to their grains and patterns. However, if the surface of the finish is too smooth, it will reflect illumination in glary high lights which hide the beauty beneath them.

The reflective power of the film is a somewhat mechanical characteristic, depending upon the smoothness of its surface plane. The gloss value of flatted lacquers or varnishes is reduced because the surface plane is broken by protruding particles of silica gel or other flatting agent added to them.

The gloss value of flatted lacquers and varnishes and rubbed surfaces is measured by means of a Photovolt Photoelectric Glossmeter, Figure 4. The instrument consists of a search unit and a sensitive meter. In the search unit, a beam of light is directed against the sample being measured. Light reflected from the sample is redirected to a photoelectric cell connected to the meter. The scale of the meter gives the reflective power of the sample in relation to a standard surface.

To prepare for the testing of gloss value, the operator scribes two areas on the back of a glass slide and measures the thickness of glass surrounding the areas. A flow coating of the sample is applied to the slide and allowed to dry for a week. Then the total thickness of the slide and the film surrounding the two areas is measured and the thicknesses of film on each area interpolated from a mathematical average of the measurements. Then the operator flows a coating of black lacquer on the back of the slide to prevent stray light from affecting the results of the test.

When the slide is ready, the operator standardizes the reading of the glossmeter by means of a piece of polished black glass supplied with the instrument. Then, he places the slide bearing the sample on the search unit so that the beam of light strikes one of the measured areas. Even minute fluctuations in the voltage supplied to the search unit produce an error in the reading. Therefore, the operator makes 10 readings of the gloss value of each of the measured areas, restandardizing the instrument between each reading. The operator makes a mathematical calculation, including film thickness and the average of the readings taken at each of the two areas, to get the gloss value reported for a sample. The test indicates whether the sample is sufficiently flatted to remove unwanted gloss or whether it contains so much flatting agent that it is hazy.

The gloss of flat finishes should be approximately the same as that of a 000 pumice rubbed finish which has a value of about 27 to 36.5 on the glossmeter scale.

Settling, Compacting

The settling and compacting of the solid particles of a finishing material occur, at least to some degree, whenever the material is stored. The compacting is progressively more pronounced in the cases of flat lacquers, sealers, flat varnishes, and fillers.

The tests of the settling and compacting characteristics of a sample provide information which receives practical application when the material is prepared for use in production. These tests indicate the amount of agitation needed to redisperse the ingredients of a finishing material in a container which has been stored before the material can be used in the plant. They can be used also to discover the maximum storage life of materials, such as flat varnishes, whose ingredients settle out and compact so thoroughly they cannot be redispersed.

A 4-ounce oil sample bottle is filled with the sample under test and allowed to stand without agitation for seven days. The settling which has occurred is then noted; it may vary from no apparent settling to several layers of material which have separated. For the test record, the amount of settling is expressed in terms of the measured height of the contents of the bottle in relation to the height of the material settled out.

The lower layers contain the material which has become more compact during the settling period. To redisperse this compacted material, the operator inverts the bottle and rights it again until all the material is back in suspension. On the test record the degree of compacting is expressed in terms of the number of successive inversions of the sample bottle necessary to completely redisperse the ingredients of the sample.

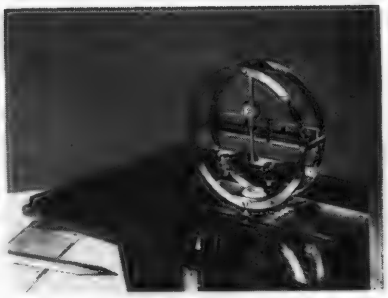

Figure 5.—Metal rims of Sward Hardness Tester rock back and forth on sample. Bubbles in tubes mounted at each side indicate testing period during which the rockings are counted.

Surface Hardness

The surface hardness of a lacquer or varnish is one of the characteristics which enables it to resist penetration by abrading particles and to maintain its appearance. The Sward Hardness Rocker, Figure 5, is one of the instruments used to measure the surface hardness of finishing materials and, though its results are modified by the smoothness of a dried film of the sample, it is widely accepted as giving a reliable index of the unyielding nature of the surface.

The instrument consists of a pair of narrow, chromium-plated steel tires mounted parallel to each other so they can roll along their edges. A weight and a pair of bubble tubes mounted between them below their center of gravity make the instrument rock back and forth, once it is set into motion.

The instrument's operation is based upon the same principle that makes a rocking chair easier to use on a wooden floor than on a soft carpet—the harder the film surface, the more times the instrument will rock because of a given force.

The bubble tubes between the tires are set at an angle to each other and marked at their midpoints to indicate how far the instrument should be rotated to begin its motion and how long the oscillations should be counted during a test.

The operator makes the hardness test on a film of the sample flow-coated on a slide and allowed to dry for one week. The instrument is set at the midsection of the slide, rolled the required distance, and allowed to begin rocking. The operator counts oscillations from the time the bubble just fails to cross the line in one tube to the time the bubble fails to cross the line in the other tube.

Flatting is not thought to soften the physical hardness of a material, but the rocker gives varying results in comparative tests of flat and glossary materials. Therefore, in the cases of flat lacquers, varnishes and of sealers, the hardness test is made on a film from a portion of the sample clarified in the centrifuge.

Specific Gravity

The specific gravity of a finishing material is an expression of its weight per unit volume at a particular temperature, compared to the weight of an equal volume of pure water at that temperature.

In company with other information learned in the series of tests performed on a new material, the measurement of its specific gravity helps fill out a complete picture of the nature of the substance. The result of this test serves to identify the material because specific gravity is an individual characteristic of a material. In addition, the value of the specific gravity is used by plant accountants to calculate the cost per gallon of those finishing materials purchased by weight.

The two main items of apparatus used to measure the specific gravity of lacquers and varnishes are a pycnometer, a small, tapering, glass flask which has a bent, capillary neck projecting from one side and is stoppered by a specially-designed thermometer, and an analytical balance sensitive to 0.1 milligram.

The operator fills the pycnometer with the sample, closes it, and wipes it clean. The pycnometer is then placed in a water bath and its temperature adjusted to 20° C., the standard temperature used for laboratory measurements. A small tube filled with an additional amount

Figure 6.—When the sample-filled pycnometer is adjusted to 20°C. in the water bath it is weighed on a balance. Comparison of this weight with the weight of an equal volume of water at 20°C. gives value of the specific gravity of the sample.

of the sample is inserted in the capillary neck to supply the contents of the flask as it contracts while cooling. When the thermometer in the pycnometer indicates 20° C., the operator removes it from the water bath, Figure 6, cleans it again, closes the neck with its special cap, and weighs it on the balance.

A mathematical calculation, which includes the water capacity of the glass flask, at 20° C. gives the weight per volume of the sample in the pycnometer. This value, compared with the known weight of water contained by the pycnometer at 20° C., gives the specific gravity of the sample at standard temperature.

When samples of nonviscous and volatile materials such as alcohols, naphthas and preformulated solvents are to be processed a Chain-o-matic Specific Gravity Balance is used. This balance measures the loss in weight due to the buoyancy of a calibrated glass plummet, suspended from one end of the balance beam by a fine platinum wire, while immersed in the sample. The physical theory involved is that any solid object—in this case the plummet—weighs less when immersed in a liquid by as much as the weight of the liquid displaced. The balance is calibrated so that the readings taken from the balance equal the specific gravity of the material under test.

Hellige Color

A common nature of their ingredients gives an amber hue to all lacquers and varnishes. The Hellige color testing apparatus measures the relative intensity of their amberness by means of their ability to transmit light.

This test is used on all new materials and has become increasingly important since the production of blond finishes has made the use of a "water-white" lacquer more desirable.

The testing apparatus is used to compare the color intensity of a sample with the color intensity of one of 18 permanently tinted amber glass filters of graduated intensities. The apparatus is a plastic box containing two glass vials and a disk which holds the filters. A section of ground glass in the back of the box allows light to pass through the vials which are seen through holes in the front.

Figure 7.—By matching light passing through a tube filled with a sample with light passing through a tube of water and numbered filter, operator identifies the amount of amberness or Hellige color of a sample.

One of the vials is permanently filled with distilled water. The operator fills the other vial with the sample of finishing material. If the sample contains pigments, it is cleared by use of the centrifuge before testing for Hellige color.

The operator places the sample-filled vial beside the water-filled one in the box. Then he holds the box in front of a strong light where he can compare the intensity of the light passing through the two vials, Figure 7. By rotating the disk in the box he places a filter in front of the distilled water which passes about the same intensity of light as the sample. The number identifying that filter is reported as the Hellige color of the sample.

The acceptable color limit of "water-white" lacquers is about 3½ on the Hellige scale. Ordinary lacquers are about 6 or 7, and ordinary varnishes run about 10 or 11.

Figure 8.—A small portion of a sample placed in an evaporation dish from a pipette bottle, weighed to determine amount, is dried in a laboratory oven to get solids content.

Solids Content

The solids content of a coating material is essentially the amount of it which remains as film after drying. The volatile solvents, needed for the solution and application of the solids, disappear into the air during the period of drying.

The operator of the test pours some of the sample into a pipette weighing bottle, measures and records its loaded weight, then repours a small amount of the sample from the pipette into a preweigher aluminum drying dish, Figure 8. He rotates the dish to spread the sample evenly over its bottom, then places it into a ventilated drying oven. He determines the amount of material placed in the dish by reweighing the pipette bottle.

The dish remains in the oven 3 hours. Then it is removed, allowed to cool, and weighed. The weight is recorded and the dish is returned to the oven, commencing a series of 1-hour heating and reweighing intervals. When the weight loss during 1 hour becomes one milligram or less, the material is considered free of solvents. The weight of the residue, compared with the weight of liquid poured into the dish, is reported as the percentage of solids in the sample.

Solids by Centrifuge

The solids which can be separated from a sample by use of a centrifuge

Figure 9.—The solids of a sample are separated from the vehicle by spinning a glass tube of it in the centrifuge. Both the solids and vehicle are measured, then are used in the determination for ash residue.

are nonsoluble pigments added to the finishing material for special purposes such as flatting or sanding. They amount to a relatively small percentage of a sample's total solids content, which includes the dissolved film-forming resins and modifiers. These stay in solution unaffected by the centrifuging action.

The amount of centrifugable solids corresponds closely to the ash residue of the sample, except for variations between the two which depend upon the presence or absence of soluble silicon, mineral driers, and combined organic matter.

The operator places a weighed portion of the well-mixed sample into a weighed vial which is then centrifuged thoroughly, with intermittent inspections, Figure 9, until the sample becomes separated into two distinct layers, the upper one of which is perfectly clear. The operator pours the clarified vehicle from the top of the vial into a weighing bottle where it is saved for further work. The insoluble pigments compacted tightly in the bottom of the vial are not disturbed by its removal.

The operator washes the compacted pigments with several applications of a suitable solvent, stirring them together thoroughly. The centrifuging action is repeated, and the washing liquid poured off and discarded. This process is carried on until the solids are completely free of all soluble vehicle.

The vial is then dried in an oven for a sufficient length of time to drive off all remaining solvent, after which it is weighed. The weight and percentage of this residue are computed and the operator notes the color, texture, and other particulars of appearance of the dried pigments.

Then he transfers the pigments to a weighed crucible, and redetermines this quantity. He ignites them carefully over a Bunsen burner under the exhaust hood where he watches their performance and the nature of the flame and smoke for indications of their composition. The crucible and its contents are then placed in the electric furnace and, when ashed, the amount and percentage of the mineral residue are computed. The same treatment is followed with the clarified vehicle.

When this phase of the work is completed, the operator combines this information with that obtained from the ash residue determination. From the data of the two tests, he is able to learn the nature of the parent compounds used in pigmenting the finishing material.

Ash Residue

The ash residue of the sample is the total of its incombustible matter which can be recovered after burning. The determination is made to discover the amount of inorganic material included in the pigments of sealers, flatted lacquers and varnishes, and to get an indication of their chemical nature. It serves as a means of identifying the sample and of gaining an understanding of the reason for its performance in other tests.

To carry out the ashing process, the operator ignites a weighed portion of the well-mixed sample in a weighed porcelain crucible, first with an open flame under the exhaust hood, and finally in an electric furnace. The cooled crucible with the residue is reweighed and the amount and percentage of the residue is calculated.

Figure 10.—A rack of panels goes into the oven for the first phase of a cycle test for resistance to cold check of a sample coating.

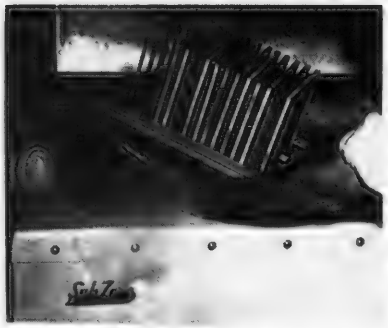

Figure 11.—Next panels are placed in refrigerated cabinet for cold phase. When chilled an hour, panels are removed and inspected.

By observing the color, texture, and general appearance of the ash, and by the use of simple chemical treatments, the operator finds the mineral components of the ash residue, which indicate the possible nature of the pigments actually present in the sample. This information is tabulated and correlated with the findings obtained later in the determination of solids by centrifuge.

Cold Check Resistance

"Cold Checking" is the term applied to the cracking which frequently appears in cabinet finishes exposed to extreme cold or to alternate warming and chilling. Both conditions may threaten the finish of a cabinet during storage, shipping, or use by the customer. Although the cracks are extremely fine, they are permanent fractures, and passageways for moisture, oil, and molds which may later ruin the appearance of the cabinet.

In order to know the cold checking resistance of a sample, panels prepared with it are subjected to two tests. The first examines its ability to withstand cycles of alternate warming and chilling; the other examines its ability to withstand increasingly colder temperatures.

The cycle test, tentatively endorsed by ASTM, accelerates the wearing-down of the cold checking resistance of the sample film as each period of heat drives off some of the semivolatile plasticizers. It is made on a set of three wooden panels 6 inches square prepared with a built-up finish system including the sample. After aging one week from preparation, the panels, set edgewise in a rack, are placed in an oven, Figure 10, for 1-hour exposure at 120° F. At the end of the hour, the rack of panels is transferred to a refrigerator at —5° F., Figure 11, where it remains for another hour. Fans circulate air around the panels in both cabinets.

At the end of the second hour, the panels are inspected by viewing them from close to a strong light which strikes the panels at an acute angle. If the finish on a panel shows checking (small cracks running at a slight angle to the grain of the wood), Figure 12, this fact is noted on the report of the sample and the panel is removed from the test.

The remaining panels are returned to the oven, repeating the cycle of the test until the finish on each panel shows failure, or until 20 cycles have been completed. The total number of cycles through which a sample passes is the test value sought, with its performance on each of the three panels being reported.

Figure 12.—Pencil points to the line of a cold check on this frosty panel.

The method of testing samples for cold checking, by progressive depression of their temperature, yields a valuable cross-check on their resistance. Furniture varnishes usually fail on one of the early cycles of the warm-chill test, presenting results which cannot be easily compared. Some lacquers withstand the 20 cycles of the first test, but that information does not indicate the resistance of the sample to a single exposure to extreme cold.

For this test, the operator places another 3 panels, coated with the sample and associated sealers and undercoaters, in a rack in the refrigerator set at 35° F.. At the end of ½ hour, if no checks have occurred, the refrigerator is set for its lowest temperature, about —80° F. At regular intervals as the temperature drops, the operator records the reading on a thermometer placed with the panels and inspects the panels. If the operator sees no checks, which in this test occur at nearly right angles to the grain of the wood and are easily visible, he returns the panels to the refrigerator, working as rapidly as possible to minimize the warming effects of handling and room temperature.

The test continues until the first crack is observed on each panel. The temperatures at which the sample first checks on each of the panels are reported as the range of the cold check-

Figure 13.—Operator places weights on a panel in the humidity box. The glass disks and paper distribute the loads evenly over the area of the sample-coated surface under test.

ing resistance of the sample. Finishes which check above —20° F. are usually considered poor in this respect.

Print Resistance

The degree of hardness or print resistance of a lacquer or varnish is equivalent to the measure of its load-bearing strength. The ability of the finishing material on a cabinet to resist taking prints of objects resting upon it is one of its most important practical characteristics.

Because the built-up finish system must be hard enough to withstand the pressures applied to it during the storage, shipping, and ultimate use of the cabinet and still present an unmarred appearance, this measurement is made when the film is subjected to conditions of high temperature and humidity representative of the most unfavorable likely to occur during the normal life of the finish.

In ultimate use, the finishing material must perform satisfactorily on a wooden cabinet. However, because many immeasurable factors enter into a test of one element on a coated wood panel, this test is conducted on both glass slides and prepared wood panels coated with the sample material.

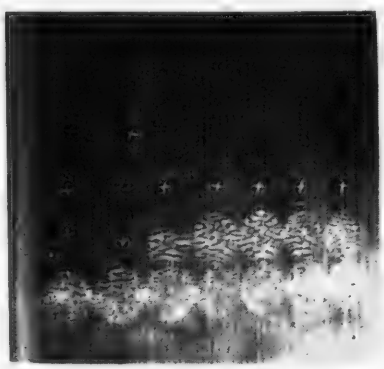

Figure 14.—Finish on this panel exhibited very poor resistance to printing evidenced by spots of fiber in the surface.

The samples on glass and wood are exposed in a humidity box for 7 hours to conditions of 110° F. heat and 90 percent relative humidity. The operator then covers the films with a sheet of soft-finish paper to equalize the pressure on the area covered by each test weight. On the paper-covered wooden panel the operator places 24 glass disks, which give uniform pressure areas, and loads them, Figure 13, beginning with the second disk, with a series of 23 weights. The pressures applied to the surface by the 24 disks range from 1.142 to 150 pounds per square foot. On areas of one-mil thickness of the paper-covered coating on glass, which have been measured by micrometer, he places a series of aluminum and brass blocks, giving a range of pressures from one to 225 pounds per square foot.

The test contiuues for 17 hours while the samples remain exposed to the extreme conditions. At the end of the test period, the operator removes the weights and paper and inspects the samples to determine the print resistance of the films. If the film became tacky, fibers of the paper remain in the film where the pressure was greater, Figure 14; if the film softened, impressions remain in the sufficient hardness to resist the pressure, no print remains in the film. When the operator records the degree of print resistance of the sample, he notes also other important characteristics, such as hazing, which may have occurred during the severe conditions of the test.

A minimum print-resisting ability of 10 to 12 pounds per square foot is regarded as an acceptable performance for a finishing material tested in the humidity box.

Film Formation

The setting or dust-free period, the tack period, and the drying period of a film of finishing material are terms used to designate apparent stages in the progressive formation of the film. When a particular lacquer or varnish is used in production, a knowledge of at least two of these three stages has important practical value.

Setting Period: The Singer Laboratory measures the setting period on samples of new materials only, because, especially in lacquers, the time is so short that it is not of serious consequence. A coating of the sample is flowed onto a glass slide, Figure 15. At regular intervals, the operator of the test drops a small amount of Fuller's Earth upon the film, Figure 16, taps the underside of the slide slightly, to distribute the load, then inverts the slide and taps it again to dislodge loose dust, Figure 17. When the film has

Figure 15.—Timing of the film-forming period is begun when sample is flowed onto a slide in full, even coat.

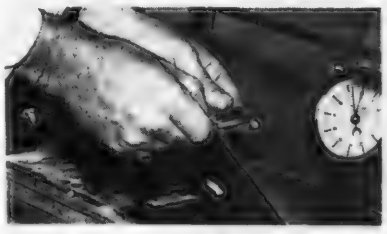

Figure 16.—Using a micro-spatula, the operator places a small amount of Fuller's Earth dust on the wet film.

Figure 17.—Then he knocks excess dust off of inverted slide by tapping its edge with a rubber mallet.

dried, he wipes any remaining loose dust from the slide. He computes the setting period of the sample as the time from the application of the film to the time when dust does not imbed itself in the film, as indicated by the dust which remains on the slide.

Tack and Drying Periods: To compute the tack and drying periods of a sample, the operator flows a coating of the material onto another glass slide, Figure 15. At suitable intervals, he places quarter-inch disks of filter paper on the film in successive rows, pressing each disk firmly in place, Figure 18. When the film dries to the point that disks no longer adhere to it, the operator removes the disks he has applied, working back from the one last applied to the disk too firmly imbedded in the film to be pulled off, Figure 19.

The tack period is the time from the application of the film to the time when the first disk was applied which shows no loss of its paper fiber upon removal. The drying period is the time from the application of the film to the

Figure 18.—Operator presses paper disks firmly onto sample film on slide.

Figure 19.—When disks pressed onto film will not stick, operator removes those he has applied, then records time elapsed from pouring of sample onto slide to application of disks that left fibers or impressions in the film to give the tack and drying times.

first time the disk-applying pressure made a minimum of impression in the film.

Because these periods are affected by the thickness of the film, a control slide, measured by micrometer, is coated with the sample at the same time as the slide upon which the disks are placed. After a week of drying time, this slide is measured again to find the thickness of the dried film.

The operator, assuming that the films on both slides would be the same if the first had remained undisturbed, may then compare the two slides and compute the tack and drying periods of the sample in terms of a standard film of one-mil thickness.

Figure 20.—Abrasive falls from funnel at top of the apparatus through the tube onto the lighted portion of the sample film on the slide, there into can at bottom.

Abrasion Resistance

The wearability or abrasion resistance of the dried film of finishing material is another of the important properties which determines its permanent value as a surface protector and beautifier on a finished cabinet. The many kinds of abrasion to which a cabinet is subjected after it leaves the plant could be neither completely included in a test process nor satisfactorily evaluated. However, the test used to measure wearability is performed by directing a stream of falling granules of a standard abrasive upon a measured thickness of a dried lacquer or varnish film. Results are compiled in terms of the amount of abrasive needed to wear through the film.

To test the abrasion resistance of a lacquer or varnish, a sample of it is flowed onto a glass slide and allowed to dry for 7 days. Then the operator places the prepared slide into the testing apparatus 30 cm. below the outlet of a reservoir for the abrasive material. A mirror reflects light upon the back of the slide at the point to be abraded.

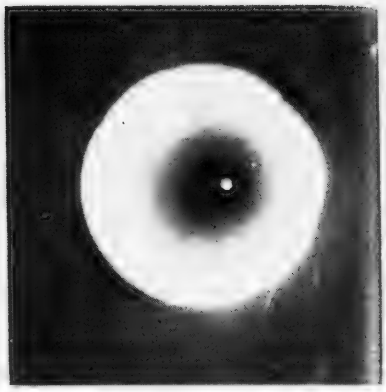

Figure 21.—The bright pinhole of light shows the abrasive has worn through film and test is complete.

The operator pours Alundum 46B, a granulated abrasive near to the diamond in hardness, into the reservoir, one kilogram at a time, and watches the lighted portion of the slide as the abrasive falls upon it, Figure 20. When the film is worn through, a bright pinhole of light appears, Figure 21. Seeing this, the operator stops the flow of abrasive and weighs the amount of abrasive used. He compares this weight with the earlier-measured thickness of the film at that point. The test is repeated to get two readings closely comparable in terms of the resistance of the film thickness to the quantity of abrasive.

Film Thickness

The thickness of the film made by finishing material is related to most of its other practical characteristics for which tests are made. For instance, film thickness must be known to understand and to calculate properly the results of examinations of the abrasion resistance, print resistance, cold checking, and gloss value of a sample. Production departments must be able to know they are applying enough finishing material to cabinets and panels.

Micrometer: For analytical purposes, the thickness of a dried film of a sample is measured by a micrometer. All films of test materials coated on glass are measured by this instrument.

When checks are made in production to determine the dry-film thickness, strips of cellophane are attached to the panels to be tested. When the panels have been coated and are dry, the strips are removed and a micrometer reading is taken. This is the most accurate and convenient method of obtaining the dry-film thickness of production items.

Elcometer: In production two other instruments are used to measure

Figure 22.—The elcometer gives a direct reading of the thickness of a dried coating on the steel plate taped to the test panel, using the instrument's ability to measure the reluctance of the coating to the magnetic field between two contacts on its base.

Figure 24.—Operator measures diameter of the film—wet spot on the lens, uses the figure to read thickness of the coating from a table.

Figure 25.—Paper masked samples are placed in metal holders, labeled and hung on rotating circular rack for graduated periods of exposure to strong, discoloring light from electric arc in center.

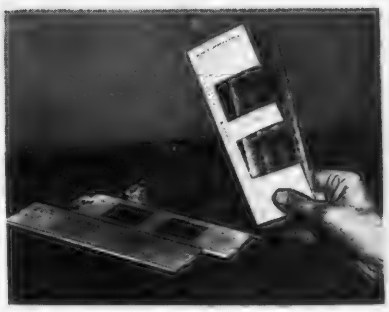

Figure 26.—Pieces of sample-coated wood and glass, removed from protective paper masks, show degrees of fading and discoloration caused by ultraviolet are light.

film thickness of finishing materials. The Elcometer, Figure 22, measures dry-film thickness, either of a built-up finish system or of a single component of the system. It employs the principle of resistance to magnetic attraction and the test film is applied by spray or roll to a small steel plate taped to a regular wooden cabinet panel.

After the coating has dried, the operator removes a piece of tape from the plate to expose uncoated metal. He places the contact points of the Elcometer against the steel and adjusts its scale reading to zero. Then he places the meter against the coating over the metal and the scale reading indicates the thickness of the film directly in mils. The film on the plate is assumed representative of the film on the remainder of the panel. To make tests of the thicknesses of additional coats, the operator replaces the tape on the steel and repeats the coating-measuring operation.

Pfund Gage: The Pfund Gage is used in production to measure the thickness of a wet film of finishing material applied to a panel. The instrument consists of a slightly convex lens, spring-mounted in a chromium-plated barrel so that it may be depressed vertically into the wet film. As the operator presses the instrument into the film to the substrate, Figure 23, the liquid spreads out along the curve of the lens covering a circular area. He measures the diameter of the circle on the lens, Figure 24, and computes film thickness by means of a table.

Figure 23.—Spring-mounted central barrel of the Pfund Gage which holds a convex lens is pressed down into the wet film surface of a production coated panel.

A correlation exists between the thickness of wet and dry films of the same finishing material and the operator can find this correlation by the use of the Elcometer and the Pfund Gage. Later, when he wants to know that enough of the given finishing material is being applied in production, he can measure wet film thickness instantaneously with the Pfund Gage and find how much protective finish will remain when the volatile ingredients of the lacquer or varnish have evaporated.

Discoloration

The instrument used for discoloration tests is the Atlas Fadometer. Specimens to be exposed to the light are placed in black-lined white paper masks in holders hung on a circular rack which revolves around the light, Figure 25. Normal exposure times in a test are 24, 18, 12 and 6 hours. Four perforated sections of the paper mask can be removed successively to make the desired exposure. A control area between the second and third sections allows the sample to retain its original color for comparison purposes.

Samples of coating materials are exposed separately and in combination on both wood and glass slips, Figure 26. This multiple testing is needed because some undercoats which may fade or show no color change when tested alone will discolor during exposure when coated. Also, though it is desirable to see the complete finish on wood, color changes in the coating materials are more easily noticed on the clear glass.

This study of color-stable finishes also reaches beyond the sale of the cabinet to the continuing quality of its appearance in the customer's sewing room. The Company's purpose is to find a combination of color-stable finishing materials which possess the more important qualities that make a tough, durable film to protect and beautify the surface.

Color

For each of the darker cabinet finishes, such as mahogany, walnut, and red maple, a special blend of color is added to the wood in the form of a stain to bring out its native beauty. In order to prevent unattractive variations in the colors of cabinets and cabinet parts, the color of the stain applied must be held as close as possible to a standard color for each type of wood.

For this purpose, judgment by the eye against a reliable standard of comparison is accepted as the most practical way of defining the color of a sample. In this test, a sample is compared with either a permanent color by which it may be identified, or with an accepted stain of known performance.

The permanent color identification makes use of the system of color defini-

tion described by A. Maerz and M. Rea Paul in their book, a Definition of Color, McGraw–Hill Book Co., 1930. The book contains 56 color plates on which eight sets of colors are graduated in small solid color blocks through 7 steps of grayness from pure color to a point where differences are indistinguishable. The total of 1,008 different gradations of color defined by the Maerz and Paul system allows ample opportunity to make a positive, permanent identification of a sample.

To conduct the test on a stain, the operator prepares 3 solutions of it in beakers. The first holds a quantity of the stain at full strength as supplied or intended for use. The second and third beakers contain the stain diluted to fifty percent and twenty-five percent of full strength. The dilution is made because undertones of color cannot be seen in the pure stain.

The operator dips 2-by-3-inch strips of white filter paper into each of stain solutions immersing about two-thirds of each strip. Then he hangs the strips to dry by means of a hole punched in their clean ends. When they are dry, he punches a quarter-inch hole in the stained end of each strip.

Taking first the strip stained full strength, the operator turns to an appropriate color plate in the M. & P. color book and lays the strip on it so that the hole lies over one of the color blocks on the page, Figure 27. By moving the strip from block to block, he selects the one which is closest to the stain color in grayness and hue. The selected color book is identified by the plate number, Roman numeral; column, capital letter, and row, Arabic numeral. This information is recorded on the report and on the unstained end of the paper slip, which can then be filed with its permanent color identification. The operator repeats the procedure with the other two stained slips and records their identifying colors.

If a comparison between a sample and an adopted stain is desired, the operator immerses strips of filter paper into full-strength solutions of each of the stains, lets them dry as before, and punches a quarter-inch hole in the stained end of each slip. By laying one strip over the other, the operator can see the color of the lower one through the hole of the upper. He then describes the differences or similarities in grayness and hue between them and records them on the report.

The test is also applicable to such finishing materials as colored fillers, paints, and pigmented lacquers. These are flowed or brushed onto sheets of non-absorbent white paper and identified or compared when dry, in the same manner as stains.

Figure 27.—Permanent identification of hue and tone of a sample is made by comparing the color of a stained paper slip with that of an indexed section of a standard color plate.

Evaporation Rate

The solvents combined in a stain determine its rate of evaporation, control the penetration of the stain into the wood, and are responsible for the effect of the stain on the surface grain of the wood.

The stains used at South Bend contain solvents of a non-grain-raising variety. The mixture of solvents used is 5 percent water, 90 percent methyl alcohol, and 5 percent ethyl cellosolve. The water is used to insure the solution of the dye powders in the stain; the alcohol hastens evaporation and prevents raising the grain of the wood, and the cellosolve controls the evaporation of the other two solvents so penetration is assured and no residue of the stain is left unused on the surface.

The operator observes, by means of this test, the time required for the solvents in a drop of the sample stain to evaporate. It can also be used to test solvents alone. He places a ½-inch disk of filter paper on a small square of clean glass and, by means of a glass tube, allows 1 drop of the sample to fall upon the disk. When the drop of stain touches the paper, the timed period begins.

The square of glass is inverted and placed on top of a can, open at both ends and raised from the table by a stand. The corners of the glass rest on the lip of the can and the paper disk remains attached to the underside of the glass by the moisture of the stain. Supported in this manner, the stain-soaked disk has free access to the air but is protected from drafts which might affect the value sought.

The operator watches the appearance of the disk through the glass, Figure 28. When the solvents evaporate, the disk loses its wet gloss, and the operator stops the watch. He runs the test ten times and averages the resulting values, then repeats the test using a stain of known performance and acceptability. The two results are compared to get the value of the evaporation rate.

Water Resistance

One of the most obvious and, for that reason, most serious failures of a furniture finish is its tendency to whiten when exposed to water. Therefore, the water immersion test, one of the simplest performed on samples, is one of the most important.

The standards for finishing materials used on Singer cabinets require a lacquer or varnish which will not whiten under normal exposure to water, such as the spilling of a glass of water. The standards allow the use of materials which whiten under abnormal exposure to water but which recover their clarity within the limits of the test period.

Water Immersion: For the water immersion test, the operator places a glass slide, coated on one side with a dried flowed-film of the sample, into a beaker, then pours distilled water into the beaker until two-thirds of the film is immersed. The remaining one-third of the film remains dry for comparison purposes.

When the film has stood in the water for 24 hours, the operator removes the slide from the beaker, wipes it carefully, and examines it. He records whether or not any whitening has occurred in the film, and the nature of it. The film is allowed to dry for 24 hours. Any film that whitens and does not clear on drying is unacceptable.

Water Patch: In an effort to bridge the gap between the laboratory bench and the customer's sewing room, the water patch test was devised. It was intended to provide a means of examining the effects of water on a sample film applied in conjunction with other elements of a finish system to a wooden panel.

After a wooden panel has been prepared with sanding, appropriate undercoaters, and the sample finish, and allowed to dry for a week, the operator

Figure 28.—Stain is dropped on a paper disk resting on the glass. The glass is inverted and operator times evaporation rate of stain with stopwatch, watching paper disk for signs of dryness.

selects an area of approximately 4 square inches on the panel and marks a line around it with a wax pencil. Then he half fills a wide-mouthed bottle with distilled water, places a thickness of cheesecloth over its mouth, and covers it with a layer of blotting paper. He inverts the covered bottle and places it on the selected area of the panel where it stands for 24 hours.

The water soon soaks through the blotting paper, wetting the finish, and the cheesecloth filament allows air to enter the bottle, compensating for water lost by evaporation.

At the end of the exposure period, the operator removes paper and bottle, and wipes the panel carefully. He inspects the extent and nature of the damage with a low-power magnifying glass and records whether or not the finish has whitened, or swelling of the wood has opened the finish in cracks. Then he tests the film with a knife to see if disadhesion from the wood has occurred.

The panel is then allowed to stand for another 24 hours and is reexamined to see if permanent damage was done by the water.

Cracking Diameter

Another in the series of observation tests is the measurement of the cracking diameter of a supported film of a sample. Although furniture finishes are not subjected to visible torsion or tension in normal service, it has been observed that the properties of the film tested in this way are related to its ability to resist cold checking. A sample which lacks the flexibility and extensibility to withstand being wrapped around a curve of relatively small diameter, checks easily under lowered temperatures.

A material of such complex nature as a lacquer or varnish cannot be tested easily for one property without the results being modified by its other properties. Therefore, this test, performed at room temperatures, gives another indication of the toughness of a sample film under conditions that tend to nullify hazards to some companion properties.

In the test, a dried flowed-film on a piece of cellophane is wrapped firmly around the circumference of eleven progressively smaller glass tubes which range in size from 1¼ inches to 1/16 inch. Because some lacquer films do not crack at the smallest diameter, the operator may fold and crease them, and some show no failure even then. The diameter of the tube around which the film cracks is given as the sample's cracking diameter.

Flow-Out

Some indication of the way a lacquer or varnish will perform in production can be gained by experienced observation of the way it flows during the film-forming period on a slide.

The operator pours the sample carefully and quickly onto the slide so as to avoid overlaps, especially in quick-drying lacquers. When the slide has dried, the operator can observe whether such peculiarities as curtains, pronounced sags, silking, extremes in film thickness, or a particularly fat edge formed during the drying period.

Knife Test

Degrees of softness, toughness, chalkiness, and brittleness are discovered by the operator when he tests the film with the pointed and rounded ends of a special knife.

With the aid of a low-power magnifying glass, he inspects the results of pushing the pointed end of the knife along the film, noting whether myriad tiny chips fly from the film, a crumbling of the film takes place, a curling sliver is cut from the film, or the film separates from the glass around the point. Then, pushing the rounded end of the knife along the film, he notes how it resists cutting, pares away from the supporting glass, or breaks away from the glass in flakes. The variable and complex nature of finishing materials does, of course, produce many varieties of the above results which the observer judges to his satisfaction.

Blunt Tool

Brittle films shatter easily under steady pressure applied by a blunt object, and mar intolerably when the blunt tool is moved across their surface. Other softer or tougher films may resist the pressure or dent under it, and perhaps show ripple marks when the tool is rubbed across them. The tool chosen for this test is a heavy spike, the sharp end of which has been rounded off to a nearly smooth ball shape about 3/16 inch in diameter. The operator supplies the pressure by gripping it vertically in his fist and pressing down on its head with his thumb.

Sandiness

Sandiness, which is due to particles in the sample disrupting the smooth formation of the film, is readily visible to the operator. In addition to dust from the air, which may have became imbedded in the film during the drying period and which can be identified easily, several other causes may be to blame for the sandiness.

The film of a flatted or pigmented coating material in which the solids have not been thoroughly dispersed may also present a sandy appearance, due to the groups of unmixed particles protruding above the surface. Materials supplied by foreign factories are quite often in this situation.

Additional Tests

The following tests attempt to predict the production properties and problems that would be involved should the materials be released for a production test. These tests will only be briefly reviewed to indicate the properties considered for the reason that they are not standardized and are conducted, with modifications, in most factories that test materials.

Stain: The foregoing tests that apply to stain are: color, evaporation rate, and discoloration.

The appearance of all new stains is checked for several shipments. This is to insure that upon repeated production, the clarity and freeness from settled particles will not be a problem.

The odor is always noted. This helps to acquaint the technicians with the stain and the solvents used.

In addition to the Color Test in group two, the stain is sprayed on the wood it is to be used with. One-half of that sample is coated with lacquer and comparisons are made. A drop of stain is placed on a water-moistened filter paper and an observation of the color separations as the stain spreads out is made.

A relative measure of the penetration is to place a drop of stain on a piece of filter paper, measure the length and width of the dried area and take the average of several trials. When spraying on a panel, observe the amount of bronzing. Wipe the hand across a dried panel and notice the material left on the surface.

Filler: When reduced to the required cut and allowed to stand for 7 days, the amount of settling and the ease with which it will return to suspension is considered.

Unreduced filler from the supplier is tested for its package life and properties.

The skinning of fillers is to be expected so the skinning times of a test filler are compared to those of a known filler.

The color of a filler is checked by placing a sample on glass and filter paper and feathering it out. When dry and checked, the filter paper sample may be filed. The color is checked on the wood intended for its use and its reaction under the top coats is observed.

The time required for flash and drying is so dependent on atmospheric conditions that only general conclusions are drawn from laboratory tests. Tests are made on glass and wood.

The filling characteristics are tested to determine the ease of towing, the ability of the filler to break off level with the pore, how long the filler can remain on the surface before towing,

and how clean a wipe-up can be assured. Open pores, pinholes and unfilled areas are checked after filling, after drying and after lacquer topcoats.

When the dry filled panel is coated with sealer, puffing and any corresponding shrinkage are noticed. The degree of puffing, the length of time required for the filler to level, and any shrinkage are considered with respect to the atmosphere, performance with different topcoating materials and the performance with fillers of known properties.

The odors and other undesirable properties such as smarting the hands or difficulty in cleaning the hands are looked for.

All fillers are checked for discoloration in the Atlas Fadometer, uncoated and coated, on glass and on wood.

Sealer: The properties in the first two groups that apply to sealers are: abrasion resistance, ash, blunt test, color, compacting, drying, discoloration, flow-out, viscosity, refractive index, sandiness, settling, solids-centrifuge and content, specific gravity.

The sealer is sprayed under standardized conditions and its flow, tendency to sag or run, and fill the pores are noted.

The sealer's effect on previously applied materials such as filler puffing, bleeding of the stain, or any change of color, when compared with a sealer of known properties, is noted.

The sanding properties and adhesion both to the wood and the effect as a part of a finishing system (under lacquer) are checked.

Lacquer: In addition to the tests conducted on sealers, cold checking, cracking diameter, gloss, hardness, print resistance, and water resistance tests are made.

The spraying test as conducted for sealers is made and for lacquer a rubbing test is made. The slip drag, speed of cutting, ease of wipe-up and final clarity are checked.

Toner: Upon receipt, toners are checked for package stability. The amount of settled pigment and the ease with which it is returned to suspension are noted.

The material is sprayed on the wood for which the toner is intended. Any evidence of mottling, streaking, inadequate flow out or crawing is looked for.

As toners differ in purpose, their opacity or transparency is compared with materials of known performances, and with respect to its contribution to the final finish.

If the toner requires a sanding, it is given this test.

The action of a filler of known performance is applied over the toner and the effect of filling and the ease of wipe up are noted.

Glaze: Upon receipt of the material, settling and skinning are noted.

Color comparisons are made similar to those for filler.

The principle properties given attention are the ease with which the glaze is wiped and its blending qualities.

The length of time required for drying and the effects of the lacquer over the sealer are also noted. As glazes have the tendency to reduce adhesion, this property is tested.

Reducers: Reducers are generally tested only for identification. These tests are specific gravity, color, odor, and the distillation range.

Evaluation of Floor Finishes

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Laboratory test methods for evaluating commercial floor materials suitable for use on maple, beech and birch floors are summarized. Twelve tests are used to screen such materials to assure adequate product performance and customer satisfaction with the finished floor. The requirements are generally accepted by the finishing industry and test procedures are taken, insofar as possible, from accepted standards and specifications. Tests described include Resistance to Liquids, Skinning Resistance, Drying Properties, Waxing Properties, Clarity and Color of Finishing Materials, Non-volatile Matter, Flash Point, Hardness, Viscosity, Elasticity, and Abrasion Resistance.

Introduction

THE TIMBER Engineering Company Research Laboratory is the official testing agency of the Maple Flooring Manufacturers Association for the evaluation of commercial floor finishes in accordance with certain specifiations. The tests described in this article have been designed to permit the use of the widest scope of suitable materials that are on the market today or which may appear from time to time. The requirements are generally accepted by the finishing industry and the procedures have been taken, insofar as possible, from accepted standards or specifications. The tests are revised periodically and are not considered entirely satisfactory in all respects, but they are felt to be reasonable screening standards which are practical for most finish manufacturers to meet.

The specifications have been compiled by the Timber Engineering Company in conjunction with the Maple Flooring Manufacturers Association for use with finishing materials to be applied to maple, beech, and birch floors. When a submitted finishing material passes the standards set forth, it is placed on an approved list issued by the Association. This seal of approval is used by the manufacturer for advertising purposes.

The specifications have been developed for the protection of the consumer and as an aid to the manufacturer in formulating serviceable products. They consist of twelve tests covering (1) Resistance to Liquids, (2) Skinning Resistance, (3) Drying Properties, (4) Waxing Properties, (5) Clarity of Finishing Material, (6) Color of the Finish, (7) Nonvolatile Matter, (8) Flash Point, (9) Hardness, (10) Viscosity, (11) Elasticity, and (12) Abrasion Resistance. (2)

The requirements described cover two basic types of floor finishes recognized by the Maple Flooring Manufacturers Association. *Heavy-Duty Type Finish* covers penetrating materials used

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typically in residential applications; *Gymnasium Type Finish* formulated to resist the type of wear typical of that occurring in gymnasiums. Nine of the twelve tests have exactly the same requirements for approval for either type of finish. However, the Gymnasium Type Finish requires a higher solids content (40 per cent minimum as compared to 28 per cent), permits a somewhat greater viscosity, and requires greater resistance to abrasion. (Taber Abrasion Index of 250 as compared to 1.0)

Resistance to Liquids

The purpose of this phase of the evaluation is to determine whether the finish is resistant to water at room temperature, alcohol, and solvent naphtha.

Resistance to water conforms to method F–5 of Federal Specification TT–S–176a (1). One coat of the finishing material is applied to a 31-gauge tin plate measuring 3″ x 5″. After drying for a period of 48 hours at a temperature between 70°F and 90°F, the plate or panel is immersed in approximately 2.5 inches of water. The end of the panel which was uppermost in drying is immersed in the water for a period of 24 hours at room temperature conditions. Following a 2-hour drying period, the finishing material cannot show any whitening nor any other visible defect, other than a very slight dulling of the original sheen.

Performance for resistance to alcohol and naphtha is checked by applying 2 coats of the finishing material to a piece of 2¼ x 12 inch strip of First Grade Maple Flooring. The wood is sanded smooth with 00 sandpaper, dust removed, and the material is applied allowing a 24-hour curing period at 70°F to 90°F between coats and after the second coat. Approximately one-inch pools of Stoddard Naphtha and a 50 per cent alcohol solution, respectively, are formed at the respective ends of the specimen and are then covered with a watch glass for 1 hour at 70°F to 90°F. The remaining solvent is then removed by blotting. Any evidence of damage, dulling, or whitening, which remains after rubbing lightly with a clean cloth causes rejection of the finishing material.

Skinning Resistance

Materials passing the standards are required to have high resistance to skinning over in a container. This test is conducted in accordance with ASTM Method D 154–47 (3) using a wide mouth glass jar of 8 fluid ounce capacity and two inches in diameter. A 6-ounce sample is placed in the jar, covered tightly, and left in an inverted position at rest in the dark for 48 hours. Upon examination, no skinning over of the surface is allowed—a slight jelling or skinning where the material surface meets the glass jar may be disregarded.

Drying Properties

The purpose of this test is to determine whether the finish sets to touch and dries hard within a reasonable period of time.

Tests are run as described in Federal Specification TT–S–176a, Section F–4 (1). Essentially, the finishing material is flowed on a clear glass panel. The panel is then placed in an approximately vertical position in a well-ventilated room at temperatures between 70°F and 90°F, in the absence of direct sunlight. The film is tested at points not less than one inch from the edges by touching lightly with the finger. The finish is considered to have set to touch when no material adheres to the finger under gentle pressure. The finish is considered to have dried hard when pressure which can be exerted between the thumb and finger does not move the film or leave a mark which remains after the spot is lightly polished with a clean cloth.

Requirements are that the finish must set to touch in not less than one-half hour, nor more than 3 hours, and shall dry hard in no more than 7 hours.

Waxing Properties

From a practical standpoint, it is important to determine whether typical wax preparations adversely affect the finishing materials applied to wood. A strip of maple flooring is finished as previously described under procedure for testing resistance to alcohol and naphtha. To one half of the wood strip there is applied a solvent type floor wax conforming to Federal Specification P–W–158 (4), and to the remaining half is applied a water-emulsion type floor wax conforming to Federal Specification P–W–151a (5). Any adverse effect of the waxes is cause for rejection of the finishing material.

Clarity and Color of Finishing Material

The clarity of the finishing material as to freedom from sediment and suspended matter is tested as specified in method 426.1 of Federal Specification TT–P–141b (6). A thoroughly mixed sample is used to fill two test tubes to within 1 inch of the top. The tubes are stoppered with clean corks and allowed to stand for 24 hours at which time any evident sediment is noted. If no sediment is present, one of the tubes is shaken vigorously and the two tubes are compared; if both tubes are free from clot, jelly and sediment, the material meets the requirements deemed necessary for satisfactory service.

Color of finishing materials is also required to be within a desirable range. For color comparison, tubes conforming to ASTM Method D 154–47 (3) are used. A sample of the finishing material is poured into a Gardner–Holdt viscosity tube and its color is compared to a series of Gardner reference standards. It is required that the sample shall not be darker than the No. 13 Gardner Standard.

Nonvolatile Matter and Flash Point

The solids content of finishing materials influences to a considerable extent the protection afforded to the floor. The determination of nonvolatile follows ASTM Method D 154–47 Par. 14 (3). A specific amount of material is placed in a flat-bottom glass dish; it is then spread over the bottom of the dish by tilting and heated for 3 hours in a ventilated oven maintained at 221° ± 4°F. Per cent solids is then calculated using the oven-dry weight of material and the weight of the original sample. Heavy-Duty finishes are required to have not less than 28 per cent nonvolatile matter; Gymnasium-Type finishes not less than 40 per cent nonvolatile.

State and local ordinances may restrict the storage and use of materials to those having minimum flash points in conformance with established regulations. The flash point test is run in a Tagliabue closed cup tester, in accordance with Federal Specification TT–P–141b (6). The flash point shall be not less than 90°F, in order to be approved under this evaluation.

Hardness

Hardness of the dried film is determined by the Sward Hardness Rocker. A film of the finishing material is drawn on a 6 x 12 inch polished glass plate using a doctor blade with a 1-mil gate opening. The film is dried for 48 hours at 75°F ± 5°F and 50 ± 5 per cent relative humidity. The film hardness is then determined under the controlled conditions of temperature and humidity using a Sward Hardness Rocker standardized to show a hardness of 100 on polished plate glass. The film hardness value is required to be not less than 12.

Viscosity of Material and Elasticity of Film

Viscosity is measured in accordance with ASTM Method D 154–47, Para. 11 (3) using Gardner–Holdt reference standards. Heavy-Duty Finishes are required to have a viscosity not greater than A2 standard; Gymnasium-Type Finishes not greater than C standard.

Elasticity or toughness of a finish is determined by proportionately reducing its elasticity by the addition of a stand-

ard solution of run-Kauri gum in pure spirits of turpentine (so-called Kauri Reduction Test). The test is made as generally outlined in ASTM Method D 154–47, Para. 17 (3). Essentially a 33-1/3 per cent solution of Kauri solution, equal to 75 per cent by weight of previously determined nonvolatile matter of the finish, is flowed on No. 31 gauge 3 x 5 inch bright tin plate. The plate stands 1 hour vertically at room temperature, is baked for 5 hours at 212°F, and is then removed and cooled for 30 minutes at 77°F. The panel is then placed, coated side up, over a 1/8-inch rod mandrel and bent double in approximately one second at 77° ± 2°F. In order to be approved, no cracks can occur over the bent area between points 1/4-inch from each side of the panel. It is considered that a finish which will resist a 75 per cent reduction with Kauri gum, on the basis of its nonvolatile content, will have satisfactory flexibility or elasticity for good service performance.

Abrasion Resistance

Naturally the best method for evaluating abrasion resistance of floor finishes is actual exposure to wear. Since such a method is costly, slow, and involves numerous variables, an alternate accelerated method is desirable. Two main types of accelerated testing which give an index of relative value are (1) the Taber abrasion test, and (2) the falling sand method. Both methods are subject to variables and neither is ideal. The method used for evaluation under this program is the Taber abrasion test.

Three flat stainless steel plates 0.03 inches thick, 4 inches square, and having a 1/4-inch center hole, are coated on one side with a thin uniform coat of material whose dry weight will be between 1.0 and 2.0 milligrams per square centimeter area of the plate. The plates are weighed before being coated and after drying for 48 hours at 75° ± 5°F. The weight of the dried finish is reduced to milligrams per square centimeter of plate area.

The cured panels are abraded using a Taber Abraser (Research Model) with CS–10 Calibrase Wheels and 500 gram torque weights on each head. Each plate is abraded until, by visual inspection, approximately 50 per cent of the coated area of the track has been worn away. The surface of the plate and of the wheel is cleaned after each 100 cycles. Following completion of the test, an Abarasion Index is calculated by dividing the cycles recorded by the milligrams of dry film applied per square centimeter of plate. A correction formula is used (based on a more precise area measurement) to compensate for human error in estimating 50 per cent wear area by quick visual inspection.

Heavy-Duty Finishes are required to have an Abrasion Index (average of 3 plates) of not less than 150; similarly the Gymnasium Finish Abrasion Index must be at least 250.

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Ovens For Drying Wood Finishes

WALLACE HERDLEIN

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THE FORCED DRYING of wood finishes became of major importance as a result of the conveyorization of the finishing lines in furniture factories. With any appreciable chain speed, it is quickly apparent that the amount of conveyor and floor space begins to get impractical for long periods of air drying. Further, continuously operating lines must perform on definite cycles and cannot depend on natural temperature and humidity conditions. It follows, therefore, that forced drying becomes a necessary part of modern production lines. The building of the furniture dryers and the heating, ventilating, and humidifying equipment required is relatively simple in that the temperature involved usually ranges from 125° to 175°. In some of the early units, the equipment for humidifying, and sometimes the heating units, too, were much more elaborate than they had need to be. Some of these complicated units—because of their very nature—were poorly maintained. Subsequently, we have made every effort to simplify the entire system. Almost all furniture factories are equipped with boilers and heating facilities using steam, and for this reason, and the fact that furniture ovens operate at such a low temperature, steam is used for the drying. In the early operations, the air passed through spray nozzles, and wet and dry bulb thermometers were used for controlling temperatures and humidities. There is nothing wrong with this method except that it is expensive and required a considerable amount of attention. With the usual temperature range for wood-finishing ovens, a simple hair humidistat is satisfactory. The use of water-spray nozzles can be avoided by simply injecting steam into the air stream.

The ovens or drying rooms have been built in a number of ways. Some have been built of plaster board nailed to both sides of a two-by-four framing and therefore had very little insulating value, while the better drying rooms were built of steel-covered panels with an inch of good insulation between the steel sheets. Most of these drying rooms have been located on reasonably thick wood floors which had some degree of insulation. Occasionally, a mistake was made by placing an oven of this kind on a concrete first floor. Obviously, these were hard to heat and hard to humidify. While we would like to see

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all ovens made of the natural or bottom seal type, most furniture ovens have conveyor openings in the side or the ends of the ovens requiring an air seal of some nature to prevent loss of hot air into the factory. Aside from the oven exhaust air, which should meet the insurance standards, any excess air discharged by an air seal is, of course, wasteful, and for this reason the seal arrangement should be designed so as to be as economical as possible. While we are interested in the manufacture of drying equipment, we are not qualified to discuss finishes. We must, of course, continue to build equipment to suit any finishing material. Most of the first dryers were built for the usual stains, sealers and varnishes or lacquers, all of which were air-drying materials. Since that time, clear synthetics, baking at 170° for about two hours have been developed, and for this reason, we believe most ovens should be designed for temperatures of 170°.

It has been the usual practice to install automatic controls for temperature and humidity. Regardless of temperature, the humidity is usually specified at 35%. We have seen a great many ovens in which the humidity-control equipment was completely out of order and which seemed to be doing a satisfactory job without any humidification, although it would certainly seem to be much better practice to maintain approximately the same humidity in the oven as generally prevails in the factory.

In setting up a complete heating system, the addition of a good humidity control costs so little extra that it could not well be omitted. Aside from the air seal or exhaust units, the heating and humidifying equipment and the recirculating fan and all accessories, including motors, temperature controls and humidity controls are usually built into a single unit or cabinet which is located on one of the walls of the oven. From this unit the heated and humidified air is distributed throughout the oven by a series of ducts arranged for the establishment of uniform temperatures. Usually the centrifugal fans in these hot air streams are provided with high temperature oils or greases and the motors and belts are also for high temperature application. The steam coil is usually equipped with a direct acting modulating control valve with the bulb in the return air stream. The humidistat is also located in the return air stream and controls the amount of steam entering the recirculating stream. Usually this latter is an "On-Off" control. Furniture ovens usually require so much floor space that if at all possible they should be located on the roof of a building with the spray booths and possibly the heating units located on the floor below.

There are two general types of conveyors for ovens—the continuous overhead trolley and the floor type. The latter may be of push-along or continuous design. Trolley conveyors have the advantage of cleaner conditions through spray booths, and work well in multiple story buildings where long continuous runs are necessary from floor to floor. Sometimes roller or pallet conveyors are used in combination with trolley conveyors.

Roller conveyors or pallet conveyors are sometimes used in a manner that permits bunching of the work in the drying ovens. Bunching saves floor space, but cannot easily be done with trolley conveyors and the advantages of the trolley system are then sacrificed to smaller floor area. With overhead ovens on upper floors or on roof tops, the floor-space problem is minimized and we get all the advantages of trolley conveyors, savings in floor space and the most efficient type oven. The type of conveyor, therefore, influences to some extent the floor space required.

In the final analysis, the oven arrangement and type of conveyor is usually dependent on a group of factors which vary widely from plant to plant. Some of these are:

1. Quantity of work
2. Factory floor space available
3. Roof space

Quite frequently ovens are installed with more thought given to how small they can be made rather than to the best design. Smaller ovens must operate at higher temperatures and for this reason are less efficient. They are also most often the ovens which produce a poor quality work and are more likely to be influenced by unusual conditions. Slower drying at lower temperatures is more foolproof, and we are sure that on this score most finishing department operators and most paint suppliers will agree. For those contemplating the installation of finishing equipment, we would recommend that the finish supplier and the equipment manufacturer be brought into a conference to discuss all of the various phases of the contemplated installation. This group should consider the work load, kind of finish, type of spray booths, conveyor and oven, and on the basis of these considerations, design equipment that will best meet all requirements, including the most effective location in the manufacturing plant, so that the utmost in quality and efficiency may be attained.

TECHNICAL SESSION VIII—Fri., May 7, 1954, 1:30 P.M.

Subject: Quality Control
Chairman: Charles Latimer
Recorder: Richard C. Calahan

"The Human Angle of Quality Control"

Keynoter, B. E. Sooy, Wolverine Carton Co., Grand Rapids, Michigan

MEN, MATERIALS, machines, and management are the basic variables which determine quality in any manufactured product. Of these, men and management have the greatest effect on quality, whether it be in the manufacture of paper and board, such as our company manufacturers, or lumber, furniture or the wide host of products that come under the term, forest products. It is universally accepted today that statistical quality control is a very important management tool and is capable of effecting major gains with operating personnel. This is especially true if the approach is approximately 90 percent psychological and 10 percent scientific.

The objectives of statistical quality control are: 1) to make production of quality as easy as possible, 2) to provide incentive for people to do a good job, 3) to provide management with good operating facts, and 4) to protect the customer's interest in the plant. Certain basic requirements must be met in order to successfully accomplish the objectives of statistical quality control. First and foremost, the quality control approach with production personnel must be a friendly one and not one of monitoring. Statistical quality control charts are to be considered as a pair of eyes for the operating personnel. Second, statistical quality control should deliver news and not history. This practise permits adjustment in operations when it will be meaningful. Another basic requirement is the delivery of facts and not opinions. Such data provides a sound basis for specifications.

Statistical quality control in practice teaches people to think in terms of variability. The returns from such a program can be expected to be found in improved quality, lower spoilage, lower costs, improved morale, reduced complaints, improved industrial relations, improved customer relations, and improved sales position. However, the note of warning with respect to statistical quality control application is: don't go overboard; don't get high-brow. In many applications the psychological aspects of statistical quality control are more important than the scientific.

Quoting from the Bolton Award papers of 1953, the "obligations of a company to its employes" include job security, personal recognition, quality of management, advancement, good communications, job training, and others. Statistical quality control functioning properly contributes in some part to each of these obligations.

Translating Quality Control Facts into Action

WILLIAM F. PRICE
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Means are described by which the interest of production and management personnel in quality control is stimulated and maintained; how simple but graphic charts can be used to develop pride in holding the quality line. Suggestions are made as to good principles in reporting to management and for the incorporation of effective quality control in company management.

TO OBTAIN AN OPTIMUM quality performance, statistical quality control data must be translated into effective action at the earliest possible moment. To accomplish this, the data must be transmitted promptly and accurately to those parties in best position to initiate corrective action. The success of any quality control program is directly proportional to the effectiveness of this translation.

It is the purpose of this paper to discuss the means by which quality control at The Singer Manufacturing Company is achieving the desired quality performance. These means include: (a) Techniques of reporting quality control data to the production personnel promptly, accurately and simply. (b) Creating an atmosphere among production personnel conducive to taking prompt action. (c) Providing quality control with the necessary authority to get action if not done voluntarily by production.

System of Reports and Reporting

In developing a system of reports and reporting, as in many other cases in the field of statistical quality control, there is no limit on the number and variety of techniques, charts, graphs, forms, etc., that can be used. To adopt the military phrase, "it all depends upon the situation", would be putting it mildly but would be the best way to describe the problem of selecting the ideal charting system. Certainly each manufacturer has his own specialized problems and no one system of

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reports and reporting can be nominated as a "cure-all". Each chart or form should be custom-styled for its particular function.

Certainly the charts will use the standard quality control techniques for $\bar{X}$ and R, c, p, np, etc., but frequently the success of an operation will depend upon the presentation of the collected material. The data should be presented as simply as possible and still furnish management with the facts desired. It must, at the same time, be capable of telling each individual operator exactly how his process is functioning. By personalizing each operation, we build up a feeling of pride within the individual operators upon whose shoulders rests the success or failure of the process.

The writer believes that the principles of simplicity and accuracy are being obtained at The Singer Manufacturing Company by the use of charts that, at a glance, give the desired information without requiring the reader to understand the underlying statistical techniques. It has been our policy to have duplicate charts on each individual operation that is under surveillance. One chart is of the typical data sheet type and is maintained by the quality control inspector primarily for a permanent record. These charts provide space for the collection and plotting of the subgroup data and also give a record of the preliminary data with the calculated control limits. The other chart is a large wall chart posted alongside the operation. These charts also show certain basic information concerning the operational characteristics and also provide space for plotting observed values.

To be used in conjunction with the quality control charts, we have developed a system of colors which are posted on the charts and designate the quality level being obtained. This color code is very similar to our modern traffic light system: stop, caution and go. Green represents the "go light" and, for us, means that the process is operating normally and in control. Yellow is the caution sign and warns us to be on the lookout for trouble because of a trend or because the points are approaching the control limits. Red indicates danger—the process is operating out of control—and is the cue to start looking for an assignable cause. These colors are posted on the charts in two ways: first, by using large colored discs which hang from the wall charts and are large enough to be seen for some distance; and second, by having all points plotted on the chart graphs with red, yellow or green pencils, depending upon the location of the points.

It is very encouraging to note the interest that follows the daily posting of the colored discs and subgroup points. The individual operator is very conscious of the color on the chart at his machine and a real feeling of competition is developed between operators to keep the charts in the green. We have attempted, and, we hope succeeded, to build up good operators by instilling a state of positive thinking. Before the collection of any preliminary data the operator is informed of our intentions and at no time do our inspectors "sneak around" watching the operator from behind trucks or conveyors. In this way, the operator does not get the idea that he is being spied upon and will continue his job in the normal operating manner. Incidentally, it is also a good idea to inform the foreman of your purpose for establishing a check on the operation. After the preliminary data have been collected and are ready for a wall chart, the foreman and machine operator are brought together and the principles of the chart explained to them. Careful thought must be given to explaining statistics to foremen and workers endowed with the old school of thought. Therefore, our explanation is concerned mainly with the color code.

Another system adopted at Singer, which has proved very successful, has been to utilize the information collected by the regular line inspectors. This information can provide valuable facts and is easily converted into p, np, and c chart form. The following two examples illustrate how this system is used.

Application Example A: For several years the line inspectors had been submitting only weekly inspection reports, which summarized, into certain broad categories, all major defects. These reports were kept on file for a month, at which time they were condensed and forwarded to the production departments. It was recognized at once that these reports had two fallacies: first, if the inspector did not keep a daily record of his defects it was doubtful whether he could obtain an accurate account by relying on his memory at the end of the week; and second, the production departments did not receive the reports until several weeks after the defects occurred and then, because of the consolidation into certain broad headings, some of the information became practically impossible to isolate.

Knowing that these discrepancies existed, we were particularly pleased when approached by one of the production departments concerning the possibility of combining a realistic report system with a program of quality control. At a preliminary meeting it was agreed that the quality control section would work closely with the production departments in obtaining the information they wanted. Since practically all the production operations were subject to some type of inspection, the selection of the operations to be checked was left to the discretion of the operating department. We felt that our mission was only to supply this information with the shortest possible delay, thus equipping production personnel with the means to take effective action to decrease the number of defects.

Deciding that the most efficient method to accomplish this would be through the use of daily inspection reports, and, since many of the operations to be checked involved the inspection of hundreds of parts daily, it was felt that a sampling technique could be used and would furnish the desired results. In order to achieve a randomized sample, each inspector was instructed to take his samples at varying times throughout the day. The inspection reports were collected daily

Figure 1.—Quality control meeting.

and, when sufficient information was received, the preliminary data were computed and the information applied to either a p or np chart, depending upon the nature of the sample size. At this time, a large wall chart (p or np type) was constructed and explained to all members of the operating department concerned. The foreman was asked to establish quality goals and a timetable for obtaining them. Figure 1 illustrates a meeting of the quality control head, line inspector, foreman and operating personnel discussing the principles of a chart prior to posting.

The standard operating procedure is to collect all reports daily and to post on the wall chart the record of the day's defects. Depending upon the relationship between the amount of defects and the quality goals, the points are plotted red, yellow or green. Although only in it's infancy, the program is progressing very well and, as originally hoped, the number of defects is decreasing. We feel this is because the people concerned are getting the information accurately and promptly and are translating the facts into action.

Application Example B: Upon the installation of the conveyor line for the assembly of desk type cabinets, we were approached by the assembly department concerning the possibility of inaugurating a quality control system on this line. Everyone was greatly interested in achieving a high level of finished product quality with a minimum of repair, and the seemingly obvious answer was statistical quality control.

Preliminary studies indicated that one of the major quality problems stemmed from defective work entering the assembly area from the finishing operations. It was apparent that this was a great psychological handicap in obtaining a high level of quality work from the assembly personnel. Hence a plan was devised to sample all incoming finished parts. This data then could be directly compared to the sampling taken at the first inspection of the assembled cabinet. Further, samples are taken at final inspection (after any hardware and touch-up repair have been done) to measure the efficiency of the repair work done and the accuracy of the first inspection.

Preliminary data in the form of "c" charts, recording the defects per unit of three sets of parts, both as they enter the assembly conveyor and after they are assemblyed as three complete cabinets, were accumulated and presented to the operation department at a meeting held to outline the quality control program to be followed. The operating departments themselves established quality goals which they would attempt

Figure 2.—Application of quality control on conveyorized operation.

to meet and a timetable for so doing. A meeting was then held to fully explain to all workers in the area what the program was, why improved quality was necessary, how the goals had been established, and what was expected of them.

Fig. 2 shows one of two large boards posted in the assembly area to give an up-to-the-minute report of quality all along the conveyor. Large colored discs on the charts are used to indicate at a glance the quality picture on each part at each major stage, as well as the overall current quality level. Red, yellow and green colors, as previously described, indicate the amount of defects. The writer would also like to mention that all of the data collected in these operations were taken by regular line inspectors and not by the quality control staff.

This program is still functioning and the results are very gratifying. In seven months of operation the number of defects has decreased decisively and we feel that this program has been very successful.

Characteristics of a Good Report

Many quality control programs have failed because of that very common ailment—"fileitis." Merely to accumulate voluminous stacks of data sheets, which do nothing but lie in the files and collect dust, will not insure the success of your program. The information that is collected should be made known immediately when the work is still fresh in the mind of the operator. This is the time to take any necessary action. This information should also be made available to management and supervision at regular intervals. The writer believes that this is being accomplished at Singer by submitting a weekly quality level report to the departmental supervisors, in whose department quality is being checked. Duplicate copies of these reports are also sent to management.

Quality reports should be given a lot of consideration and should not be just another report to be written on Monday mornings. Mundel[1] lists the following principles that should be applied to management quality reports: (1) Confined to items of major interest and importance, (2) Circulated, not withheld, (3) Concise and to the point, (4) Factual and unbiased, (5) Regular:

It is certainly not easy to incorporate into one report all of the above listed principles. I am not contending that the quality reports used at Singer are the ultimate in perfection and utilize all of Mundel's principles but I do wish to present them for what assistance they might offer others in preparing such report forms. Fig. 3 pictures one of our weekly quality reports to management and intermediate supervision. We have designed our forms with the idea in mind of comparison, simplicity and ease of reading. The reports present pictorially a floor plan of the department in which the quality is being checked and show the general location of the check operations. The quality level being obtained is designated on the report by the use of our conventional color code: red, yellow and green. Each operation is distinguished by a number inscribed in a circle and further explained in the report legend. These circles are then colored according to the quality level being obtained for the week. This very simple system enables the reader to determine the overall quality picture

Figure 3.—Weekly quality level report to management.

with a minimum of reading time required. I would also like to mention that we maintain in the office large scale replicas of the reports on which we keep a day-to-day account of the quality level of each operation.

Our work also entails the control of quality of incoming hardware parts obtained from our own organization and from outside suppliers on an acceptance sampling basis. Incidentally this involves the sampling of approximately two hundred different parts. Besides keeping on each hardware item

[1] Juran, J. M. 1951. "Quality Control Handbook." Ed. 1, McGraw-Hill Book Co., Inc., New York.

a quality history, which shows such information as method of manufacture, sampling plan, and percent defective of each shipment, we have a large wall chart that gives an up-to-the-minute account of the quality level of all parts.

Quality-Mindedness for Everyone

So that the maximum harvest can be reaped from a quality control program, a state of quality-mindedness must be established, if not already present, and maintained with and between management, supervision and workers. Assuming that the top levels of management are convinced of the importance of a quality product and are sincere in their actions to make such a quality program a success, it is then up to supervision, the quality control technicians, and the man behind the machine to keep the ball rolling.

Although it is sometimes a large and time-consuming task, the best means of endowing individual operators with quality-mindedness is through personal contact. This is the best method of building up a state of positive thinking within the operator and it is through this thinking that a fair operator can become the best man in the plant. The operator should understand that quality makes and sells the product and it is to the benefit of his personal well-being to make the product as good as possible. Sometimes, however, this understanding alone is not enough. Every man should realize how good workmanship can contribute to a better product, and suggestions concerning his job should be encouraged. Possibly an occasional "shot in the arm" might be needed to keep the operator moving in the right direction.

The above assumption that management and supervision are already pushing the quality program is sometimes not true. The reluctance to embark on the good ship "Quality" is many times the downfall of an otherwise excellent quality control program. This program of selling quality control to management is a large subject in itself and is beyond the scope of this paper. However, it is of prime importance that quality be the rule rather than the exception and it is vital that everyone gets into the act.

Quality-mindedness is a condition which frequently may not exist as such but one which must be created and, for the most part, continually cultivated. To develop this quality-conscious atmosphere at Singer, we have a continuously operating quality-promotion program. This program includes a progress quality control training program that has been given to approximately one hundred persons. This course has been given to all members of management, most foremen and

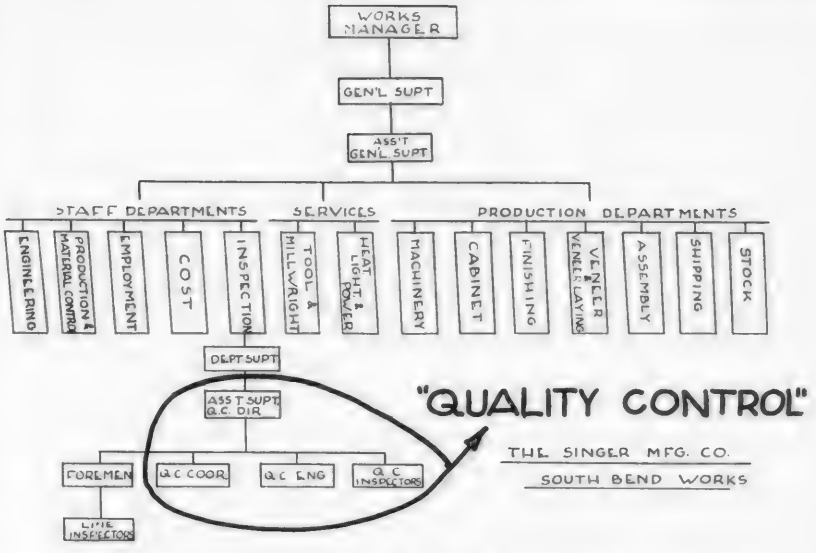

Figure 4.—Organization chart showing position of quality control administration.

set-up men and nearly all engineering and time study personnel. As the quality control program advances into other parts of the plant, additional courses are given to the personnel in these areas. The training program consists of five 1½ hour sessions, which include both lectures and practical exercises on the technical aspects of quality control. A rather extensive training manual was prepared for the course and is used as an everyday reference book for the people who have completed the course. To drive home the importance of a quality product, management, at the weekly staff meetings with supervision, is constantly stressing the needs for maintaining a state of quality-mindedness at all levels in the plant.

Also, in the quality promotion program, we have posted throughout the plant a series of quality control posters which are furnished by an outside firm. Although the comments from workers concerning these posters have been both pro and con, we are convinced that they are injecting a feeling of quality-consciousness into the factory personnel. This is further substantiated by an opinion poll conducted throughout the plant, where people, selected at random, expressed their opinion concerning the quality-promotion program. These statements were unsigned and the consensus was that the program was succeeding in promoting quality. The cost, incidentally, is quite small.

To further promote quality, our plant publication provided a center spread telling of the quality control program and showing pictures of some of the quality inspectors performing their various quality checks. This personalized touch was another method used to reach the plant worker and to promote a feeling of quality-mindedness.

A quality control program which fails to create a spirit of co-operation and quality mindedness among the "men behind the machines" is doomed to almost certain failure. The statistical techniques for attacking the quality problems which we have previously described are merely tools—aids in the improvement of quality—and are not an end in themselves. Quality must be continually promoted. Without this spirit of "quality mindedness" among the workers, supervisors and management, no amount or type of inspection will secure the level of quality we wish to attain.

Organizational Set-Up

To provide quality control with the necessary authority to obtain action, it is extremely important that the quality control director report directly to top management and be on the same organization level as the engineering, purchasing, manufacturing planning and production functions.

Even with this direct line of communication to management, it should be emphasized that the conventional chain of command should not be bypassed when negotiating a quality problem, unless it is apparent that all efforts will be blocked at the lower echelon and it is therefore necessary to resort to the top management recourse. In some organizations, however, where it is the established practice to take problems involving a quality decision to top management, sometimes little or no action is taken. In most instances, this is not due to a lackadaisical managerial attitude, but often is caused by an untold amount of red tape and tie-ups in the organizational communication system.

So that immediate action can be taken, it is best to have the individual most closely associated with the problem investigate the situation and if possible remedy it immediately. In most cases this person can be the quality control inspector who works alongside the machine operator. Certainly, this is not always possible, but generally the policy of starting investigations at the lowest level of authority will result in the quickest action. However, if no attempt is made to alleviate the difficulty, the alternative then exists of either climbing up the chain of command or using the direct line of communication to management. It is recommended, however, that all concerned parties be contacted and allowed ample time to make corrections before advising management of the situation. The unspoken threat of taking a problem to management is often the cure for many ills.

We have installed at The Singer Manufacturing Company a standard procedure for all quality control inspectors to follow in cases where trouble is detected. In all instances where a discrepancy is apparent and points go out of control or are approaching the control limits the following action is taken: (1) Check all measurements and computations. (2) Check instruments used in making the measurements. (3) If trouble continues take five more subgroups and inform the machine operator. If the trouble cannot be solved at the operation or if cooperation is not received the foreman should be advised. (4) If no action is taken by the foreman the quality control engineer should be informed, who then will contact the department supervisor or if necessary inform management. This procedure will insure top management that in the case of defective work the information will be brought promptly to the necessary personnel and appropriate action will be taken.

Since quality control is very closely associated with purchasing, engineering and production, it is very important that an atmosphere of co-ordination and co-operation prevails. Juran[1] describes how this co-ordination can be achieved through the following organizational devices:

1. Through a common supervisor: This device is very useful when everyone reports to the same supervisor. However, in cases involving men from different departments, only their departmental supervisors have a common supervisor who is generally the plant superintendent.

2. Through a staff organization: This can be accomplished by having a staff man who collects facts at the work level in each department and makes recommendations for action.

3. Through a "junior board of directors": This plan is to have younger executives consider problems which would otherwise probably fail to secure the attention of the top executives.

4. Through precedent: Unfortunately the "what was good enough for Grandpa is good enough for me" approach is not always satisfactory. Whereas precedent is usually very predictable, its weakness lies in the fact that sometimes its basis is unsound.

5. Through established written procedure: This normally assures the manufacture of a standard product.

6. Through joint committee: A consolidation of ideas is obtained by utilizing committees composed of representatives from all departments.

The author recognizes the situation that all business enterprises have their own personal peculiarities and it would be presumptuous to expect the organizational set-up of one to fit the needs of another. Therefore the writer will refrain from attempting to present an organizational chart that can be used as a guide for all industries. However, for the sake of presentation, the author would like to show how we, who perform the quality control function, fit into the overall picture at Singer. Fig. 4 illustrates how, in the Singer organization, quality control operates on the same organizational level as the production departments and at the same time has a direct line of communication to management.

Conclusion

Statistical quality control has become an increasingly important factor in the modern day method of manufacturing, and ever-mounting evidence points to its successful use in the furniture making industry. The Singer Manufacturing Company, South Bend Plant, after better than three years' experience in the actual application of statistical quality control techniques, has obtained gratifying results in decreased waste of materials, fewer rejects, and greater employee efficiency. In the highly competitive furniture market, characterized by a trend toward lower product prices coupled with higher material and labor costs, a quality control program is well worth its weight in gold if operated effectively.

This paper has attempted to present the methods by which quality control data can be promptly and effectively utilized. These include an adequate system of reports and reporting; an organizational set-up that enables quality control to function as a top level operation; and last, but certainly not least, the importance of maintaining an atmosphere of quality-mindedness.

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5. Mueller, R. K., 1950. "Effective Management Through Probability Controls." Funk and Wagnalls Co., New York, in association with Modern Industry Magazine, New York.
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Discussion

E. P. McMahon (Nickey Brothers): What quality characteristics do you check at the veneer jointer?

Mr. Price: We use a p chart at the splicer but keep track of individual defects which includes defects resulting from the jointing operation.

Mr. L. Mc Donough (Chriscraft Corp.): Can you give me details on the quality posters you mentioned?

Mr. Price: We receive these posters from the Elliott Service Co., Mount Vernon, New York. They are published weekly and the cost is quite nominal. We conducted an opinion survey in our own plant to evaluate the posters and the results indicate they are having quite a favorable effect on our employees.

Dimensions and Tolerances For Machined Furniture Parts

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The manufacture of good furniture requires that parts be fitted properly. Poorly fitting parts means lack of structural integrity and inferior appearance. If one subscribes to the theory that wood cannot be machined accurately but that parts must fit closely, then the only solution is a considerable amount of expensive hand fitting in the assembly operation. If however, it develops that wood can be machined accurately, this expensive hand fitting can be reduced to a minimum. Research at the Wood Products Laboratory at North Carolina State College has indicated that it is possible to machine wood to very close tolerances with the aid of statistical quality control techniques.

Significance of Tolerances

WHEN FURNITURE is custom made one article at a time, as is the case with the hobbyist in his home workshop or with the craftsman in his small furniture shop, the problem of dimensions and tolerances is rather easily solved. Each part is made when it is required and fashioned on the spot to fit with the other parts which are to comprise the piece of furniture. When the furniture manufacturing operation increases in size and partakes of mass production techniques, the problem becomes more acute and difficult of solution. In mass production operations individual parts are manufactured in quantity and then fed into the assembly operation at the appropriate time and place. Under these circumstances, the determination of which item from the group of "A" parts is to be assembled with a particular item in the group of "B" parts in a specific piece of furniture is likely to be purely a matter of chance. Accordingly, it is necessary that some degree of interchangeability of parts be possible. It must be presumed that any of the items of part A can be assembled with any item of part B. No wood machining operation will yield all parts with precisely the same dimensions.

The problem then resolves itself into one of insuring that the variation in the dimensions of mating parts is not so great as to produce articles of questionable utility. The problem may be illustrated by considering the matter of fitting a flush front drawer into a chest of drawers. If the drawer is to fit satisfactorily, the proper relationship must exist between the length of the drawer front and the length of the rails above and below the drawer. If the length of the drawer front is too small as compared to the length of the rails, the drawer will have a loose fit and an unsightly crack will be present at each end of the drawer. On the other hand, if the length of the drawer front is too great as compared to the length of the rails, the drawer will not fit at all or will stick when opened and closed. One solution to this problem is to permit the drawer to fit loosely on the theory that this is the lesser of two evils. This procedure will result in furniture which is inferior in appearance, and when the same principle is applied to the machining of mating structural parts, it is likely to result in a product with questionable structural integrity and a short life expectancy.

An alternative solution to the dilemma of mating parts is to make the male part oversize and then reduce it in size until a satisfactory fit is achieved in a hand fitting operation during the final assembly. This procedure has the disadvantage of being very expensive. Further, it is incongruous when it is considered that the original machining operation is almost invariably accomplished on a machine which is capable of machining wood to an accuracy of plus or minus a few thousandths of an inch.

A third solution is to exercise close control over the original machining operation. Such close control would permit the machining of mating parts as close as possible without permitting interference in the fitting of the parts.

The problem of achieving a satisfactory fit of mating parts is, of course, not unique with the furniture industry. The same problem is faced by other fabricating industries using wood, metal, plastics and other structural materials. Most of these industries have approached the problem by precisely specifying critical dimensions and tolerances on blueprints and then controlling the machining operations to insure that dimensions are within the specified tolerances.

The practice of precisely specifying dimensions and tolerances on working prints has never been extensively adopted by the furniture industry. Dimensions are usually specified in the form of a model of the piece of furniture on which the dimensions are physically measured or by means of patterns or rods. Tolerances are usually not specified. A variety of reasons have been given for failure to specify tolerances.

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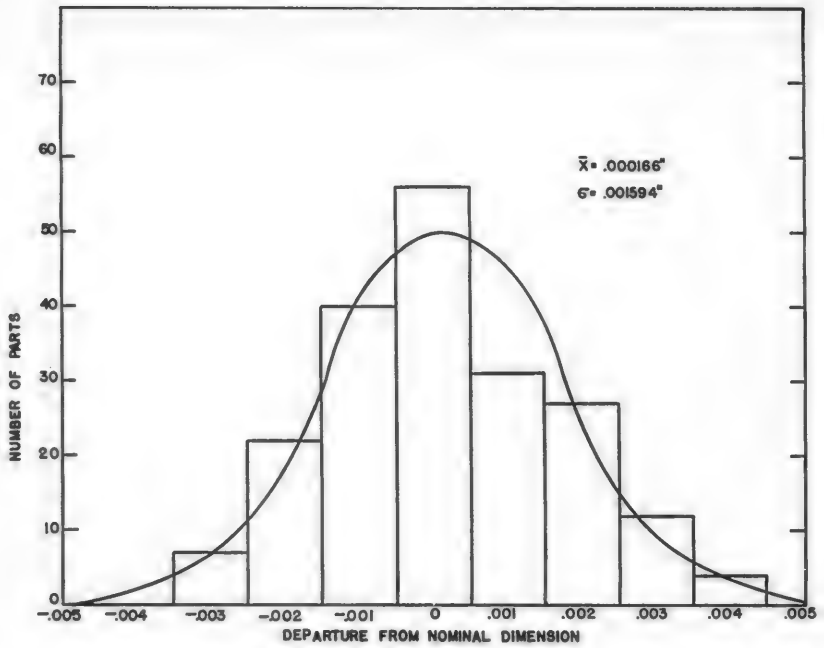


One reason which is frequently advanced is that tolerances can't be used in the furniture industry because furniture parts have to be made to an exact size and cannot vary. This statement is not compatible with the facts. Variation is present in any repetitive manufacturing operation. It is to be expected and accepted. The best that can be hoped for is that this variation will be controlled within such reasonable limits that the item being produced will have the maximum utility. If the manufacturing organization is to so control the variation, the reasonable limits must be specified. The best method devised to date for specifying reasonable limits is the written tolerance.

A second commonly encountered reason for not specifying tolerances in furniture manufacture is that wood and woodworking operations are so nonuniform that it is not reasonable to expect to use tolerances in the way that the metal working industries do for example. As a matter of fact, the precision that it is possible to achieve in woodworking machining operations is almost invariably grossly underestimated. It will be shown later in this report that woodworking machining operations can be very precise. Tolerances can be reasonably specified and of an order of magnitude compatible with the precision of the operation involved. In truth, tolerances are almost invariably used by the furniture industry but they are unspecified and unofficial shop tolerances. The length of a part may be specified by the plant superintendent as 17-3/4 inches, light. To the machine room foremen this might mean that the parts should under no circumstances exceed 17-3/4 inches in length and if many of them are less than 17-11/16 inches he will be in trouble with the cabinet room foreman. Such unofficial shop tolerances seldom reflect the basic accuracy and precision of the machining equipment, and accordingly they result in excessive time and labor in assembling and fitting of finished parts. Pittman and Johnson[1] have shown by plant tests that the establishment of dimensional tolerances through use of suitable gages resulted in a reduction of about 8 percent in direct cabinet room labor.

Precision in Wood Machining

If tolerances are to be specified for wood machining operations it is necessary to know something about the basic accuracy and precision of the machining equipment. The information required to evaluate any piece of machining equipment can be obtained by measuring the critical dimensions of finished parts. With most types of wood machining equipment such as rip saws, planers, molders and tenoners there are two primary sources of variation when the machine is well constructed and properly maintained. These two sources of variation are:

1. Machine variation—the differences in dimension among successive pieces coming from a machine in a single setup. These differences reflect the precision of the machine as a piece of manufacturing equipment.

2. Setup variation—the differences from setup to setup in the departure of average part dimensions for a setup from the nominal part dimensions. These differences measure the ability of the setup man to make the machine do what he wants it to do. They also reflect the quality of the gaging equipment supplied to the setup man and the quality of the adjusting mechanisms on the machine.

It can be shown that measurements of successive dimensions from most wood machining operations are normally distributed. Figure 1 is a frequency histogram of 199 measurements of the thickness of drawer sides dimensioned on a molder. The data are recorded as departures from the nominal thickness measured in units of .001 inch. It will be noted that this distribution resembles rather closely the familiar bell shape of the normal distribution as shown by comparing the histogram with the superimposed graph of a normal curve having a mean and standard deviation corresponding to those of this group of thickness measurements. All of these measurements represent a single setup of this molder. Hence this normal curve describes the machine variation.

Figure 2 shows four similar frequency distributions representing successive setups on the same machine—in this case again a molder. Each of the frequency distributions reflects the variation from piece to piece within a setup. The failure of the four distributions to be centered at zero indicates the variation between setups. When poor gaging equipment is used in setting-up and where setup techniques are poor, the variation from setup to setup may be significantly greater than the variation within setups. Under these circumstances, a machining operation may be quite inaccurate even though the machine being used has a high degree of basic accuracy.

The analysis of variance method provides a good way of evaluating the two components of variation in a machining operation. Table 1 is an analysis of variance table representing the operation of machining a group of furniture parts to width on a molder. The variation from setup to setup proves to be highly significant when compared with the variation within setups, using an appropriate statistical test. Under these circumstances, the between setup variation, since it represents the greater part of the total variation, would furnish most of the basis for the setting of reasonable tolerances. Table 2 indicates the percentage of parts which could be expected to fall within various limits about the nominal dimension. If more accurate gages were used in setting up the machine, the variation could be reduced substantially. Table 3 is an analysis of variance table for another molder which was set up with an accurate gage measuring to the nearest .001 inch. In this instance the tolerances are determined almost entirely by within setup variation. Table 4 provides a basis for evaluating the machine variation in this molder. A comparison between Tables 2 and 4 will

[1] Pittman, H. B., Jr., and E. S. Johnson. June 1952. Cost Savings in Furniture Manufacture by Accurate Dimension Control. Bulletin of Southern Furniture Manufacturers Association.

reveal the difference between a good and a poor machining operation. If a tolerance of ± .005 inch was assigned to furniture parts to be moulded, Molder A could be expected to yield 28.86 percent of acceptable parts, while Molder B would yield 99.58 percent of acceptable parts. Where dimensions are not critical it may well be that the kind of accuracy obtained with Molder A is satisfactory and that the additional precision which would accrue from the use of better setup gages would not be worth the extra cost. Under these circumstances, the tolerances would be set at some greater value. If the tolerance was set at ± .04 inch, Molder A would yield 99.73 percent acceptable material on the average. Where dimensions are critical, however, it would certainly be more economical to obtain accurate machining to close tolerances than it would be to do inaccurate machining and invest heavily in excessive cabinet room time and hand fitting.

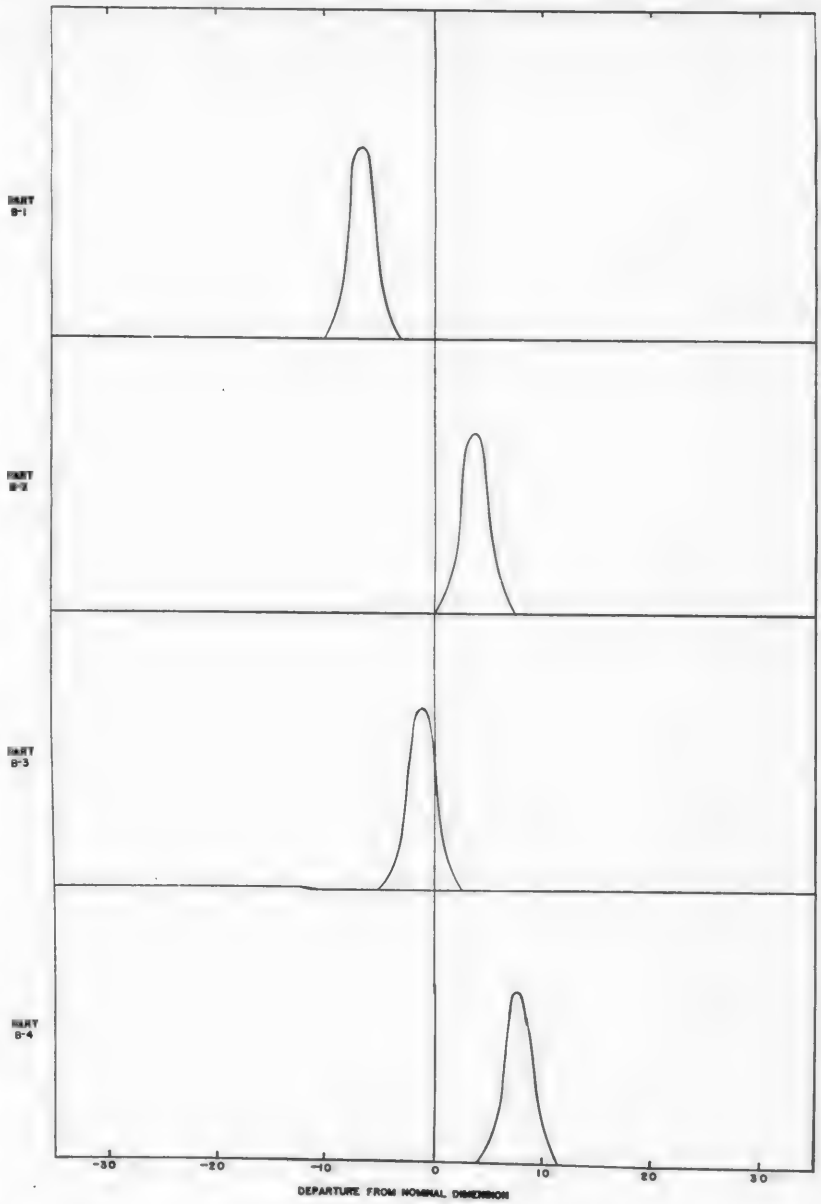
Specifying Dimensions of Mating Parts

When the precision of machining operations is known, it is possible to establish what the nominal dimensions of mating parts ought to be. Rice[2] has described a technique which is suitable to the solution of this problem. Returning to the problem of fitting a flush front drawer into a chest of drawers, it is possible to establish the proper dimensions for the drawer and the rail if the precision of the machining operations producing these parts is known. For the purpose of illustration, assume the following specifications:

	Inches
Length of rail between shoulders	32.6250
Minimum clearance required to avoid drawer sticking and to permit swelling with change in moisture content	.0625
Standard deviation of the machining operation dimensioning the rail to length (σR)	.0030
Standard deviation of the machining operation dimensioning the drawer front to length (σD)	.0038

The problem is one of determining what length should be specified for the drawer front. Since both the rails and the drawer fronts vary in length, the possibility always exists that a short rail will be assembled with a long drawer front and the clearance will be less than the specified .0625 inch unless the length of the drawer front is specified very small. The manufacturer can assign a probability to the occurrence of this event, and based upon this probability a dimension can be specified. If the manufacturer is willing to accept a condition in which a clearance less than .0625 inch occurs no more frequently than one in each hundred times, on the average, then the length of the drawer front can be determined. The standard deviation of the difference of two independent variables is calculated from the formula:

$$\sigma D - R = \sqrt{(\sigma D)^2 + (\sigma R)^2}$$
$$= \sqrt{(.0038)^2 + (.0030)^2}$$
$$= .00484$$



Reference to a table of areas under the normal curve reveals that 1 percent of the area under the curve lies beyond 2.33 standard deviations from the mean. Accordingly:

Difference between length of rail and length of drawer front = (2.33) (σD − R) + (minimum clearance)

Table 1.—ANALYSIS OF VARIANCE, MOLDER A

Source	Degrees of freedom	Sums of squares	Mean square	F	Significance	Estimate of
Between setups	7	.044562	.006366	318	Significant	$\sigma W^2 + N\sigma b^2$
Within setups	312	.006209	.000020	---	---------	σW^2
Total	319	.050771				

$\sigma W^2 = .000020$

$\sigma W = .0045$

$$\sigma b^2 = \frac{\sigma W^2 + N\sigma b^2 - \sigma W^2}{N}$$

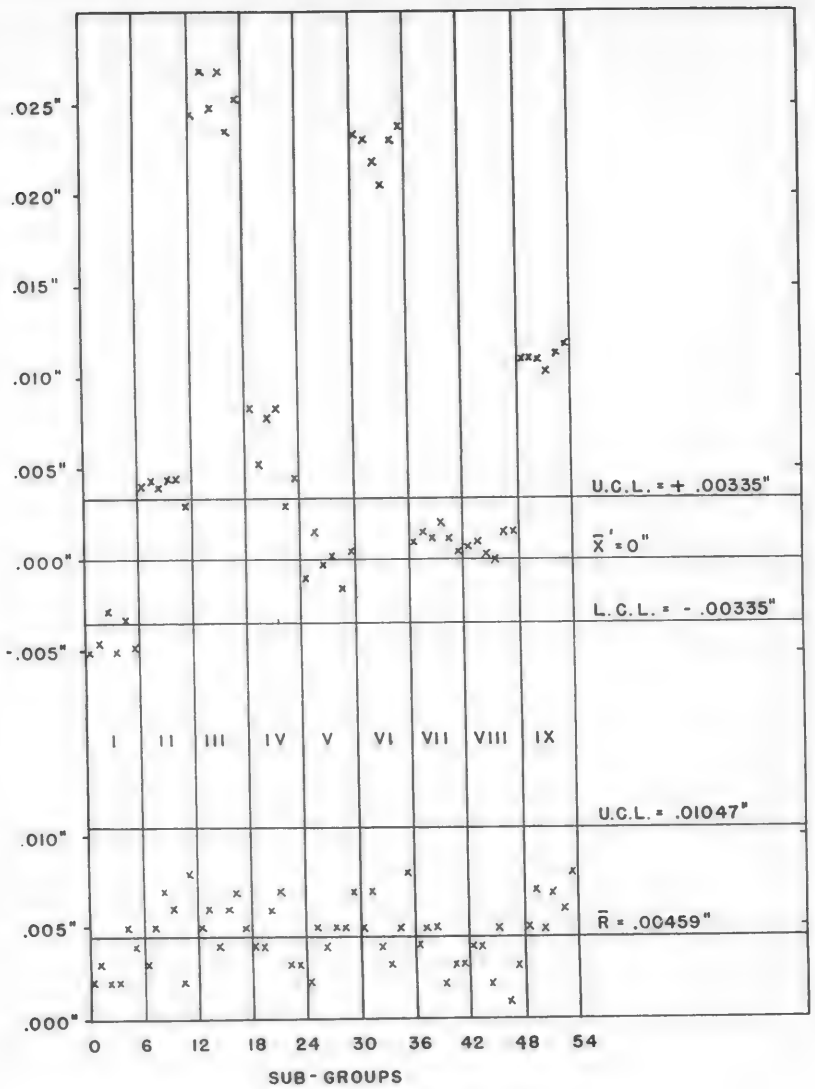
$$= \frac{.006366 - .000020}{40}$$

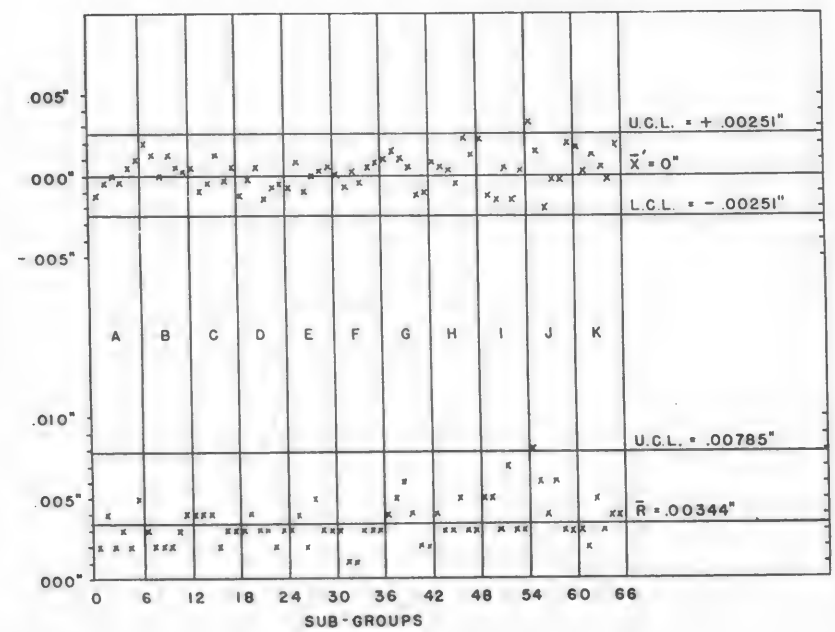
$$= .000159$$

$$\sigma = \sqrt{\sigma b^2 + \sigma W^2} = \sqrt{.000179}$$

$$= .0134$$

[2] Rice, W. B., Setting Tolerances Scientifically. Mechanical Engineering Vol. 66, pp. 801-803. December 1944.





$$= (2.33)\ (.00484) + (.0625)$$
$$= .074$$

Therefore the length of the drawer front should be specified as:

$$32.625 - .074 = 32.551$$

Quality Control in Wood Machining Operations

If dimensions and tolerances are to be precisely prescribed for machined wood furniture parts, it is necessary that the machining operation be subject to close control. Machining to dimension is an operation which would appear to be ideally suited to the use of control charts for X and R. The principal difficulty encountered is that in most machine rooms a specific machine may produce hundreds of different parts and if the plant is small, it may produce a relatively small number of each part. In this situation the inspection costs involved in preparing separate charts for each part would be prohibitive. Fortunately, it has been found that this is not necessary. Instead a single continuing chart can be maintained for each kind of machining operation performed by a machine. Figure 3 shows such a chart for molder operation. It is the conventional control chart for X and R with standard given prepared according to the A.S.T.M. Manual[3]. The standard for this Master Control Chart is zero and represents the specified dimension of the part. Individual points on the chart are deviations from the nominal dimension in .001 inch units. The control chart is based upon subgroups of 4 pieces. Eleven parts are represented on the chart, no two of which were actually the same width. This Master Control Chart is applicable where accurate gaging equipment is available making it possible to get precise setups. Under these circumstances, parts can be pooled on a single control chart. The chart in Figure 3 shows good control. Figure 4 shows a similar control chart where a coarse steel rule was used for settingup the machine. The lack of control apparent makes it obvious that the setup technique is too crude to be controlled by this charting technique. If it is necessary to use a setup gage which yields a significant difference between the varia-

Table 2.—MOLDER A

Limits Nominal dimension, inches	Percentage of pieces machined expected to fall within specified limits
±.001	5.58
±.002	11.53
±.003	17.42
±.004	23.58
±.005	28.86
±.010	54.68
±.020	86.64
±.040	99.73

[3] A.S.T.M. 1951. Committee E-11, A.S.T.M. Manual on Quality Control of Materials. American Society for Testing Materials, Philadelphia, Pa.

tion between setups as compared to the variation within setups, then the control chart should be modified so that the control limits are located on the basis of the between setup variation. This Master Control Chart method developed at the North Carolina Wood Products Laboratory[4] makes it possible to reduce the number of control charts necessary in a machine room to one for each kind of machining job done on each machine. These charts are then used each time the appropriate machining operation is accomplished regardless of the overall dimension of the part processed.

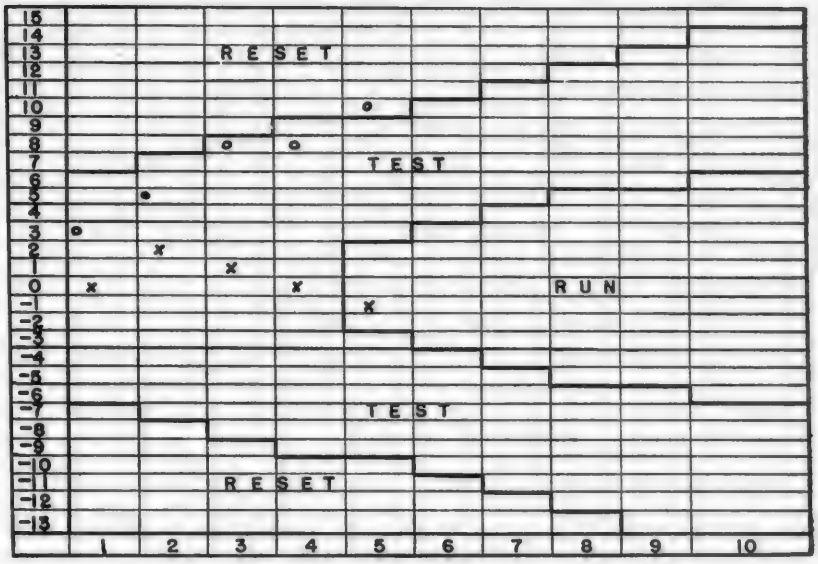
The X and R chart can be very useful to factory management in the control of wood machining operations. Control charts provide the data on machine capability necessary to the intelligent setting of tolerances on machined parts and provide the basis for the control necessary to meet the tolerances in production operations. The control chart will indicate when setup is being properly accomplished and when the machine is operating improperly. The use of the Master Control Chart with standard makes possible the use of statistical quality control charts in machine rooms where many dissimilar parts are produced in small unit quantities. The cost of inspection and chart maintenance should be amply repaid in reduction of waste, rework and hand fitting of parts and in increase in uniformity of product quality.

Accurate Machine Set-up

It has already been shown that the greatest opportunities for improving wood machining operations lie in obtaining better machine setup. This requires not only suitable gaging equipment, but a logical method for quickly deciding when a setup is correct. Burr[5] has described a simple procedure for using sequential sampling methods to accomplish this purpose. A variables sequential plan is devised based upon the known variability of the machining operation involved. When the machine has been set up, consecutive pieces are measured until a decision is made either to run or reset. Figure 5 shows such a sequential plan adapted to a wood machining operation. The procedure for setting-up with such a reset-run card is as follows:

A. Measure the first piece out of the machine after setup and plot or punch its value in Column 1 on the card. If the point falls in the "reset" area, stop and improve the setup. Otherwise, run another piece and measure it.

B. Add the value of the second sample to the first and plot or punch the cumulative result on the card. Continue until a decision is reached to run or reset. According to Seder[6] reset-run cards of this sort have been used very satisfactorily by floor inspectors at the Hamilton Standard Division, United Aircraft Corporation, in the operation of automatic screw machines. While it is theoretically possible to continue to retest for an indefinite period using this technique in practice, the number of pieces which have to be measured to reach a decision is usually small. With inexperienced operators on woodworking equipment, a test of this procedure showed the average number of pieces required to be measured per setup was 9 and the maximum required to reach a decision to reset or run was 12.



The manufacture of good furniture requires that parts be fitted properly. Poorly fitting parts means lack of structural integrity and inferior appearance. If one subscribes to the theory that wood cannot be machined accurately but that parts must fit closely, then the only solution is a considerable amount of expensive hand fitting in the assembly operation. If, however, it develops that wood can be machined accurately, this expensive hand fitting can be reduced to a minimum. Research at the Wood Products Laboratory at North Carolina State College has indicated that it is possible to machine wood to very close tolerances with the aid of statistical quality control techniques. Most woodworking machines have a high degree of basic accuracy. Very few of them are operated in such a way as to take advantage of this high basic accuracy. The use of good quality control techniques will permit the fixing of precise dimensions and tolerances and operating in accordance with these dimensions and tolerances. These practices can be expected to produce for the furniture industry the advantages they have produced for other industries: decreased waste, rework, and salvage and increased uniformity of product quality.

[4] Ginn, T. J., 1951. Application of Statistical Quality Control Techniques to Furniture Machining Operations. Thesis in library of The North Carolina State College, Raleigh, N. C.

[5] Burr, I. W., January 1949. A New Method for Approving a Machine or Process Setting—Part I, Industrial Quality Control.

[6] Seder, L. A., 1951. Chapter on Quality Control in Screw-Machine Operations in Quality Control Handbook edited by J. M. Juran. McGraw-Hill, New York.

Table 3.—ANALYSIS OF VARIANCE, MOLDER B

Source	Degrees of freedom	Sums of squares	Mean square	F	Significance	Estimate of
Between setups	10	.0000618	.00000618	2.14	Not significant	$\sigma W^2 + N\sigma b^2$
Within setups	253	.0007312	.00000289	----	----------	σW^2
Total	263	.0007930				

$\sigma W^2 = .00000289''$

$\sigma W = .0017''$

$$\sigma b^2 = \frac{\sigma W^2 + 24\ \sigma b^2 - \sigma W^2}{24} = \frac{.00000618 - .00000289}{24}$$

$$= .00000014$$

$$\sigma = \sqrt{\sigma b^2 + \sigma W^2} = \sqrt{.00000303}$$

$$= .00174$$

Table 4.—MOLDER B

Limits Nominal dimension, inches	Percentage of pieces machined expected to fall within specified limits
±.001	42.80
±.002	74.98
±.003	91.46
±.004	97.86
±.005	99.68

Discussion

J. A. Clement (Victoriaville Furniture Company): Before we can put in a program such as you have outlined, is there not a standard tolerance that could be used in the absence of any data at all?

Mr. Bethel: The sort of a program I have outlined here would logically be a later development, perhaps the second or third step after starting a quality control program.

Mr. E. P. McMahon (Nickey Brothers): Perhaps the approach to Mr. Clements problem should be to develop machine capabilities and then use these. If they do not then produce satisfactory results in assembling the article, new equipment is indicated.

Mr. Bethel: Yes, that approach might be quite helpful.

L. Toth (The Singer Mfg. Company, South Bend, Indiana): What do you consider an accurate gauge?

Mr. Bethel: I would say that, in general, steel rules or calipers capable of measuring in 32nds and 64ths of an inch would be adequate. Certain isolated jobs, such as measuring veneer thickness, will require instruments capable of measuring in thousands of an inch.

Survey of Grades in the Hardwood Plywood Industry

JOHN L. BUTLER

Manager, Laboratory and Inspection Service, Hardwood Plywood Institute, Atlanta, Georgia

This paper discusses the results of a survey to determine the points of difference between grading practices of the Hardwood Plywood Industry and grade requirements set forth in the Hardwood Plywood Commercial Standard CS35–49.[1] During the course of this investigation, panels deemed to be under-grade by their failure to strictly comply with commercial standards were classified into one of twenty defect categories indicative of the reason for the rejection. An analysis of these categories reveals the need, in certain categories, for increased vigilance on the part of quality control personnel and suggests an additional need for more realistic grade descriptions.

Introduction

THE ADOPTION of a commercial standard by any industry is made only after many reviews of the basic text have resulted in a set of quality requirements acceptable to a majority of those persons associated with the product being standardized. These requirements have been scrutinized by both production and merchandising men and the final draft, as published, represents the combined, considered opinions of experts in their field. The proof of the applicability of a standard, however, comes only after it has been placed in actual use. It is then that any shortcoming becomes most evident and a basis for movement towards a correction of the published standard may be obtained.

Such was the case with Commercial Standard CS35–49, Hardwood Plywood. In the months following its effective date (Dec. 1, 1949) there appeared increasing signs that many manufacturers were adhering to grade designations set forth in previous issues of the commercial standard or were deviating in some manner from the permissible defects as set forth in the various grade descriptions. As a result, a survey was initiated for the purpose of determining the points of difference between the actual grading practices of the industry and the grade requirements set forth in the Hardwood Plywood Commercial Standard CS35–49.

The period of the survey was from September 1950 through April 1951. Data was obtained from a total of some 2,400 panels examined in eleven mills located in five southeastern states.

Grades Designated As One, Two Or Three

The majority of manufacturers contacted were found to be using three grade designations; No. 1 (good), No. 2 (sound), No. 3 (reject). In several instances, however, mills using highly figured face veneers designated them as grade "A" considering them superior to the No. 1 grade. Since the volume of this "A" grade material was exceedingly small, the highly figured veneers were not considered in the final data.

Samplings Made At Random

The stacks of plywood panels selected for comparison with CS35–49 grade requirements were taken at random from the manufacturers' shipping and finishing departments. Each stack bore the grade designation as determined by the company's graders. The quantity and grade examined varied with the material available at the time the mill was visited.

Sample Compared With Grade Requirements of CS35-49

Using the company grader's designation as a basis, each panel was then examined for conformity to the nearest comparable grade under CS35–49. As an example; a stack of panels may have been designated by the manufacturer's graders as Grade 1 (good) with a Grade 3 (reject) back. Since the current standard recognizes an intermediate quality back as No. 3 and designates a reject back as a No. 4, the panels in question would have been examined under the rules set forth for Grade 1–4 plywood. In several instances, however, some backs being called No. 3 (reject) by the manufacturer were found to more closely comply with the current requirements for No. 3 than those for the reject or No. 4 grade. Grading in such instances was on a No. 3 basis.

Defects Classified

In examining any group of panels, defects exceeding those permitted under the current grading rules were analyzed and tabulated under one of twenty defect classifications. In a panel where more than one type of defect exceeded the prescribed limits only the single most outstanding defect was considered. A separate tabulation was used

[1] Hardwood Plywood, Commercial Standard CS 35-49.

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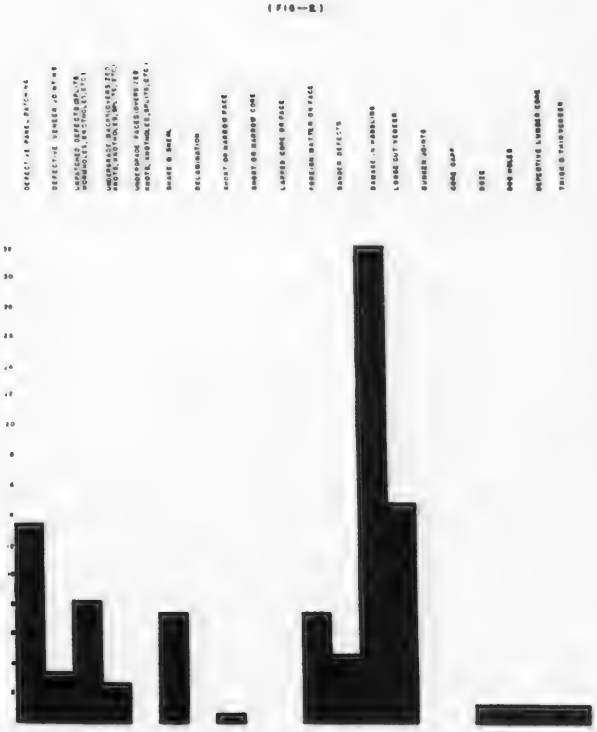
FREQUENCY OF OCCURRENCE IN PERCENT OF SPECIFIC DEFECTS IN ALL GRADES

(FIG—1)

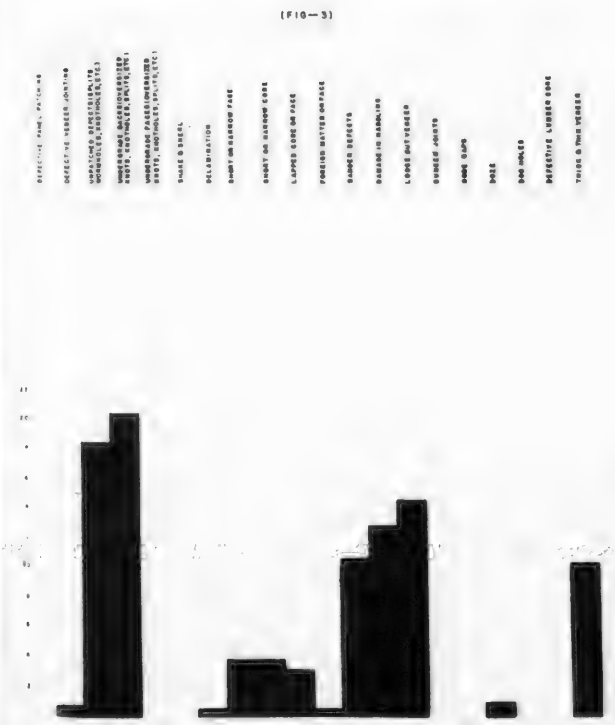
FREQUENCY OF OCCURRENCE IN PERCENT OF SPECIFIC DEFECTS IN GRADE 1—1

(FIG—2)



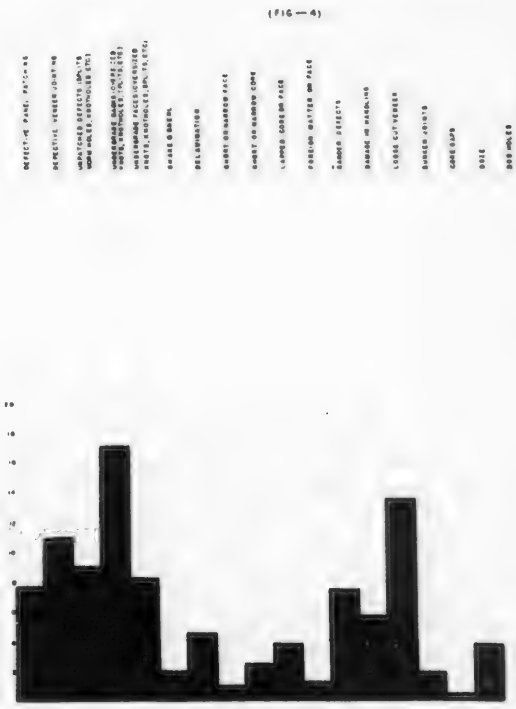
FREQUENCY OF OCCURRENCE IN PERCENT OF SPECIFIC DEFECTS IN GRADE 1—3

(FIG—3)

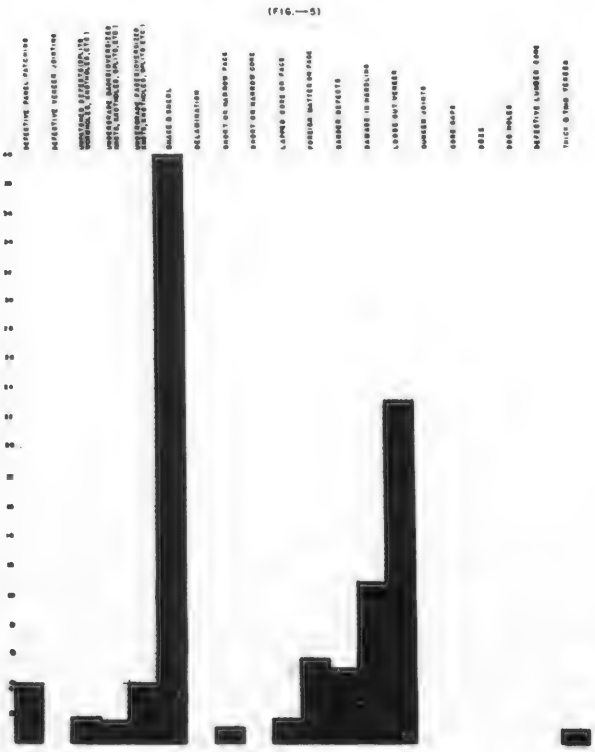


FREQUENCY OF OCCURRENCE IN PERCENT OF SPECIFIC DEFECTS IN GRADE 1—4

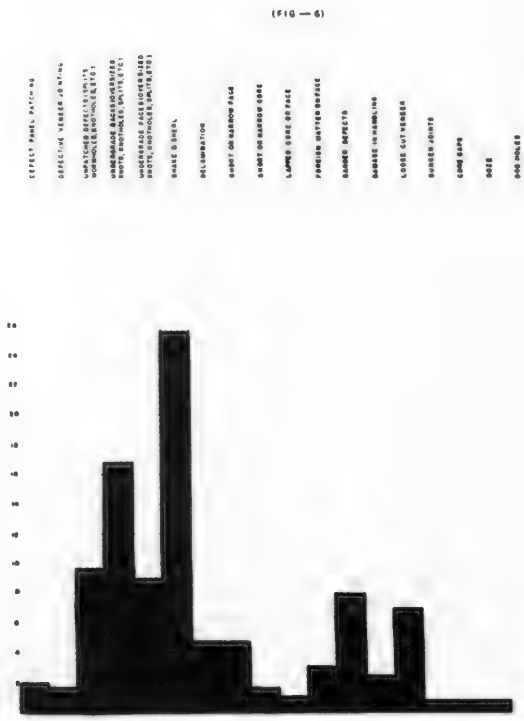
(FIG—4)



Frequency Of Occurrence In Percent Of Specific Defects In Grade 2-2



Frequency Of Occurrence In Percent Of Specific Defects In Grade 2-4



for each mill and for each grade designation examined. On completion of the survey, the frequency of occurrence of each defect classification was determined as a percentage of the total number of panels in which defects were found. This was done first for all grades and then for individual grades. These percentages were interpreted in the form of bar graphs and are here presented in Figures 1 through 6. Basically the bar graphs establish the fact that points of difference do exist between actual grading practices and the grading requirements set forth in the commercial standard and in this respect accomplish the primary purpose of this survey. I should, however, like to pass on to you some additional observations on the source and appearance of some primary defects and in addition several thought provoking facts which I believe become most evident as you study the graphs.

Six Primary Defect Classifications

Frequency of occurrence of any defect classification varies with each grade. Using Figure 1 as a guide, however, we are able to determine that a majority of the excessive defects encountered occurred within six classifications. In order of their importance, they may be listed as: shake and snerl, loose cut veneers, undergrade backs, unpatched defects, damage in handling and sander defects. We will consider each of these six individually so that attention may be called to the grades most affected by them and, when applicable, to the actual conditions contributing to their being.

Shake and Snerl: From the standpoint of individual grades, this defect appeared to be of primary concern in Grade 2 faces (Fig. 5 and Fig. 6). Shake appeared most often in Tupelo Gum and was usually limited to a small panel area. Snerl, a local term descriptive of torn grain and usually associated with inherently cross grained woods or areas immediately surrounding knots or burls, was in general less objectionable than shake. Often snerl was almost completely sanded out and was discernable only by a slight difference in light refraction. The appearance of this defect in grade one panels was usually attributable to adverse lighting in grading departments.

Loose Cut Veneers: This defect appeared as a rather high percentage in all grades of panels. A considerable number of panels showing this defect had been laid up with multi-piece faces in which one or more of the strips making up the face had been spliced or taped loose side out. Heavy sanding was responsible for bringing the loose cutting to the surface of a lesser number of panels. Cases were also observed where variable density of some peeler logs produced areas of extreme looseness affecting the finished panel surface.

Undergrade Backs: Applies primarily to the back grades (No. 3 and No. 4 (reject)). The primary difficulty encountered was with wide splits and knot holes of slightly greater diameter than permitted under the specification.

Unpatched Defects: The common failing in most grades was openings of minor proportions that might have been patched or filled and the intended grade of the panel maintained.

Damage in Handling: Although not specifically mentioned in grading rules it was felt that this classification was within the intent of the paragraph on "General Requirements (Workmanship)". Many manufacturers were surprised at the large percentage of panels showing some form of physical damage. Causes varied from the scarring of faces by chips and slivers trapped between faces at the trim saw, to indentations left by loose nails in the pallets, and broken ends attributable to accidents in shifting loads in process.

Sander Defects: Varied considerably in their nature ranging from the

marked depression left when a sander was shut down while the panel was still in the machine, to sand through along the edges or ends of the panels.

Defect Classifications Can Be Divided Into Two Major Categories

As we considered the twenty defect classifications used in this survey, it became apparent that they might be divided into two basic categories. Those defects which are inherent in the wood itself such as knots, burls, shake, snerl, etc., and those which are basically of a manufactured nature such as dog holes, delamination, thick and thin veneer, loose cutting, sander defects, defective patching, etc. Referring to Figure 1, we found that when all grades were considered as a group 64.9 percent of all defects recorded fell in the manufactured defect category. This is the group which is of the greatest concern to plant quality control personnel. These defects are for the most part independent of log quality and can be materially reduced, if not eliminated entirely, by the application of improved manufacturing techniques and other elements of quality control.

Application of Survey Data

Observing that several years have passed since the survey was completed, it would be a natural question to ask what use has been made of the information to date. Actually, it has contributed to a number of accomplishments. Increased activity in quality control applications is certainly one result. A result which is typified not only by the increased vigilance in manufacturing techniques as they affect surface appearance but by the ever increasing flow of material being received in the Hardwood Plywood Institute laboratory for a routine check of bond integrity. More recently the survey information played a part in drawing up the basic HPI grade standards governing faces and backs of hardwood plywood. These grades are somewhat more realistic of the capabilities of present day logs and tend, through the use of name grades suggestive of the panel usage, to minimize the confusion attendant to the number designation of the commercial standard.[2]

While the HPI grade descriptions are considered an improvement over those set forth in CS35–49, they are not intended to revise the commercial standard grades. It is recognized that revision can be proposed only after a thorough and complete analysis of all problems which a revision might be expected to solve. While this first survey might be considered a step along the way, others must follow to bring the data up to date and to provide for a greater coverage of the industry. In addition, there are many other phases of the standard which would have to be investigated such as bond requirements, sampling and testing procedures.

[2] Behm, R. D. How Hardwood Plywood Makers Fight for Markets. Wood and Wood Products, January 1954.

Discussion

F. M. Berry (Brunswick–Balke–Collender Co.): In CS 35–49, is there anything that covers shipping damage?

Mr. Butler: Only the general statement relative to packing (Par. 3.2 of CS 35–49)

Mr. Berry: What levels are set in CS35–49 for looseness of cutting of veneer by percent and depth of lathe checks.

Mr. Butler: CS35–49 requires that "veneers shall be tight . . .". In practical application this is interpreted to mean that the face veneers shall be cut tightly enough to where lathe checks shall not telegraph to the surface under normal conditions of finishing and subsequent use. The guage for tightness of cut for inner plies is more liberal. First, the greater thicknesses naturally tend to cut more loosely and secondly, a degree of looseness is often desirable in some species to assure a flat panel. We therefore take the point of view that veneers shall be as tightly cut as possible without unduly sacrificing panel stability or finishing qualities.

Applications of Some Statistical Quality Control Techniques in the Manufacture of Veneers and Plywoods

EDWARD P. McMAHON

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Explains theory of statistical control and its application to process control, waste control and scrap control. Other important benefits resulting from the use of statistical control are described.

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Introduction

ONE OF THE MAJOR PROBLEMS confronting the woodworking industry today is the fight to maintain present markets for the industry's products, to recover old markets, and to develop new ones.

The extent to which we are successful in this fight depends upon our ability to furnish the consumer with wood products of the proper quality to stand up in service, and at a price which is competitive with the products of other industries trying to sell to the same consumer. The maintenance of this proper quality-cost ratio is of course a problem faced by all industries in a free enterprise system. Any new tools modern management has developed which deal with this quality-cost problem therefore deserve to be tried out by an industry if it is to remain competitive.

Such a tool which has been developed in comparatively recent years is statistical quality control. Some authorities have described quality control as the sharpest management tool developed in the last half century. The woodworking industry has been slow to try it out however, compared to other progressive industries, many of them direct competitors.

This new approach to the quality-cost problem takes advantage of the fact that the quality variation of any manufac-

FIGURE 1-A

FREQUENCY DISTRIBUTION OF AVERAGES OF FIVE SUCCESSIVE 3 DICE THROW TOTALS (THREE DICE BEING USED FOR EACH OF THE INDIVIDUAL THROWS)

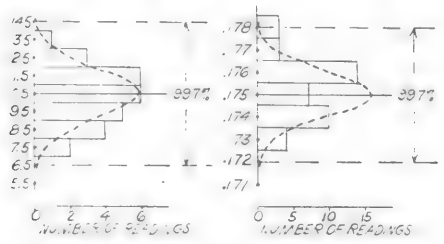


FIGURE 1-B

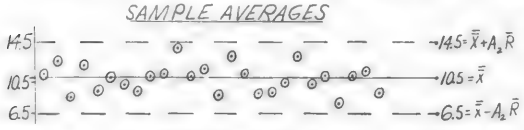
FREQUENCY DISTRIBUTION OF THE AVERAGE OF FIVE SUCCESSIVE THICKNESS READINGS TAKEN AT RANDOM ON GREEN THICKNESS OF 1/6 ROTARY CUT POPLAR VENEER

FIGURE 2

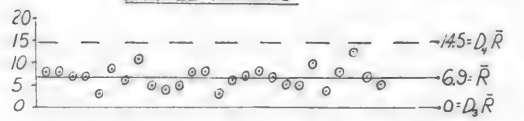
CONTROL CHART ON DICE THROWS

{ FOR SAMPLE SIZE=5, CONTROL LIMITS FOR AVERAGES = $\bar{\bar{X}} \pm A_2\bar{R}$ = 10.5 ± (.577)(6.9)
{ FOR SAMPLE SIZE=5, CONTROL LIMITS FOR RANGES = $D_4\bar{R}$ AND $D_3\bar{R}$ = 0 & (2.9)(6.9)

SAMPLE AVERAGES



SAMPLE RANGES



tured product can be described by certain statistical laws based on the theory of mathematical probability.

Statistical quality control is the name applied to a group of practical techniques, based on statistical theory, whereby these laws are harnessed and put to work controlling the very quality variation which they are known to describe.

Considerable literature[1] has been published in recent years describing how application of these techniques in a wide variety of industries has led to rather striking improvement in quality with a corresponding decrease in the cost of quality. This improvement in the quality-cost ratio has resulted from the reduction of defectives, scrap, rework, waste, and inspection and production costs.

General Theory

A description of the entire group of practical techniques which make up the full tool kit of statistical quality control would be beyond the scope of this paper. Only one of the most elementary, yet at the same time one of the most powerful of these techniques will be illustrated by the applications that follow. This particular technique is known as the statistical quality control chart.

Before we deal with actual application of this technique it would first be appropriate to at least take a brief look into some of the theory behind the control chart, to see how to construct one, and to see how this previously mentioned "harnessing" is accomplished.

If you made successive throws of three dice simultaneously, recorded the dice totals in groups of five, calculated the average of such successive subgroups, the frequency distribution in Figure 1A would be representative of the variation you would expect to get under these conditions.

Now if the dice are thrown in an unbiased manner and if the dice themselves are honest, certainly it would be true to say that the observed variation here is only that which we would normally expect due to the laws of chance —because the laws of chance are the only thing operating here to produce the observed variation.

Notice that the frequency distribution in Figure 1 is symmetrical with respect to its mean, has a general bell-shaped appearance, and shows that the most frequently obtained subgroup averages tend to cluster about the mean. The farther out toward the tails of the distribution we go the less the probability of obtaining, by chance, extremely large or small subgroup averages.

The smooth curve superimposed on this frequency distribution has a mathematical equation, and is known as the normal probability curve or the normal curve of variation. The equation appears to have been originally developed by Abraham De Moivre and explained in 1733 in a mathematical treatise.[2] At that time De Moivre believed it had no practical applications other than as a solution of problems connected with games of chance.

Somewhat later, however, Gauss used the curve to explain the theory of accidental errors of measurement in the field of astronomy. For that reason, the curve is also sometimes known as the "Gaussian" curve.

Today we know that the mathematical equation of this curve explains the variation pattern not only of games of chance and measurement errors, but in addition an amazing number of widely different phenomena in our environment. Examples range from the variation patterns observed in the basal diameter of egg capsules of a certain marine snail to the variation patterns of many quality characteristics of different industrial products.

The truth of this statement is illustrated by Figure 1B which shows a frequency distribution of the results of thickness checks with a dial micrometer on the green thickness of 1/6-inch rotary cut poplar veneer.

As in the case of the dice throwing game, Figure 1B is a frequency distribution of the averages of subgroups of five readings. Notice the similarity between the two frequency distributions. Both are seen to be symmetrical about their means and to have a general bell-shaped appearance. The reason that they are alike is that the same mathematical equation of the normal law explains the variation pattern of both.

This equation describes the relationship between the magnitude of a subgroup average and the probability of its occurrence. By entering tables[3] already calculated for us by the mathematician we can determine, in the case of the dice game for example, that the probability of obtaining by chance a subgroup average which differed from the mean value by more than plus or minus 3.9 would be 0.997, or about 3 times in a thousand.

The limit lines for this 99.7 percent probability have been drawn in on the frequency distribution in Figure 1. Within these limit lines then we would expect most of the subgroups averages to fall as long as only the normal chance variation were present in our dice game. In fact we would expect points to fall outside these limits no more often than three times is a thousand (1.000–.997).

Therefore since this event has such a relatively small probability of occurring under normal conditions, if the event did occur we would be pretty safe in concluding that conditions were no longer normal. Or as we say in quality control language, an "assignable cause" has probably appeared on the scene. In the case of our dice, we might suspect a biased manner of throwing or perhaps someone had substituted dishonest dice.

Exactly the same analogy holds for the lathe operation. Between the 99.7 percent probability limits, we would expect subgroup averages to fall most of the time as long as only the normal causes of thickness variation are present. There might be a thousand and one of these little causes all at work to form the normal variation pattern of

[1] "Industrial Quality Control". American Society for Quality Control. Milwaukee, Wisconsin.

[2] Croxton, F. E., and Cowden, D. J. 1939. "Applied General Statistics", Prentice-Hall, Inc. pp. 266.

[3] Rider, Paul R. 1939. "An Introduction to Modern Statistical Methods", John Wiley and Sons, Inc. New York, N. Y. pp. 194.

FIGURE 3

QUALITY CONTROL

CHARACTERISTIC MEASURED-GREEN THICKNESS

(1/6 ROTARY CUT POPLAR)

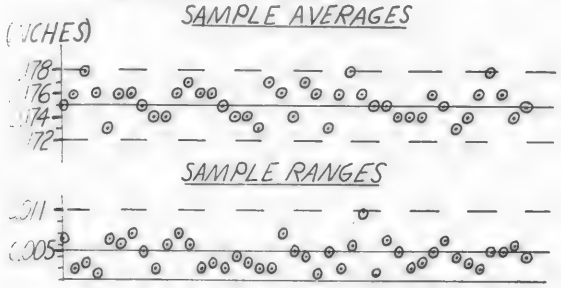
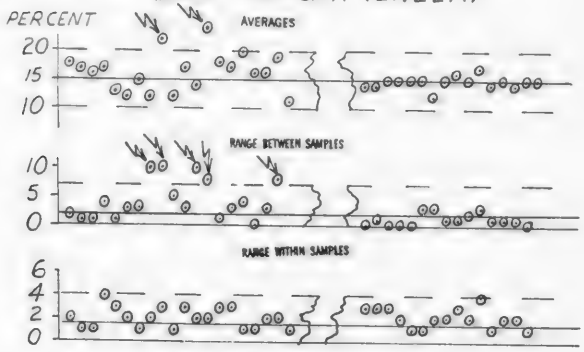


FIGURE 4

QUALITY CONTROL

CHARACTERISTIC MEASURED-MOISTURE CONTENT

(1/28 RIFT CUT OAK VENEER)



this machine. An attempt to list them would be like attempting to list the reasons why the height of rebound of a ball would never be the same even though always dropped by some release mechanism located at a constant distance above the floor.

These 99.7 percent probability limits then form one criterion for telling us when and when not to look for trouble in an industrial process, where we are trying to control quality.

Two different kinds of errors are possible here We may make a Type I error where we waste time, money, and production effort looking for trouble when there is really none there. The degree of quality variation that caused alarm was nothing more than the normal pattern of variation which is inevitable for our particular process. Or, we may make a Type II error where we fail to look for trouble when it really is there, and suddenly realize that the whole day's production must be scrapped, the good sorted from the bad, all because we failed to detect and eliminate the assignable cause of abnormal quality variation when it first appeared.

In a wide variety of industries, it has been found by experience that these 99.7 percent probability limits form the economical breakpoints to tell when and when not to look for trouble so that the total cost of committing both Type I and Type II errors is at a minimum. These limits are referred to as statistical control limits or three-sigma limits. They can be located by measuring off a distance on either side of the mean equal to $A_2\bar{R}$. A_2 is a constant obtained from statistical tables[4] for a given sample size, and $\bar{R}$ is the average range of at least 20 successive subgroups of measurements taken on a process.

Figures 2 and 3 show the same data contained in Figure 1 unscrambled from the frequency distribution and plotted on a control chart in order of production, in the case of the thickness data, and in order of throwing in the case of the dice data. The bottom part of the control charts shows the subgroup ranges plotted about their average value in relation to their probability limit. The upper and lower control limits for ranges is obtained by multiplying $\bar{R}$ by D_4 and D_3 respectively. For a sample size of five, $D_4 = 2.11$ and $D_3 = 0$.

By classifying the variation in two different ways, averages and ranges, you are generally in a position to more effectively detect and eliminate assignable causes than when either averages or range is used alone.

The fact that no charts contained points outside of control limits indicates each is operating under a state of statistical control. For the lathe this means that we are getting the best possible control of thickness this particular man-material-machine industrial combination is capable of turning out. The basic inherent process capability is being 100 percent realized. If when this ideal state of affairs is realized and you are still not meeting specifications, the only alternatives you have are either to widen specifications, basically alter the nature of the process to change its natural variation pattern or use 100 percent inspection to sort out non-conforming product.

The statistical control chart approach to economical process control therefore has the following characteristics:

1. The taking of relatively small samples at relatively frequent intervals concentrating on early detection and elimination of defectives. This is in contrast to the traditional idea of quality control involving relatively large samples at infrequent intervals in some final inspection effort which attempts to sort good product from bad to insure outgoing quality.

2. Using averages and ranges of small subgroups as a more sensitive indication of process changes than would be obtained by considering only individual readings in the sample.

3. Use of statistical control limits which harness the governing laws of variation, and put them to work to minimize the total cost of various combinations of Type I and Type II errors.

4. Location of control charts as near the origin of the quality variation as possible, and plotting the charts in order of production. In this way early detection and elimination of assignable causes of serious quality variation is possible soon after they appear.

5. Emphasis on the more dynamic idea of control of outgoing quality through defect prevention rather than relying on final inspection alone to accomplish this function by sorting out non-conforming product. Now let us discuss some representative applications showing how these control charts are used.

Use of Statistical Control Charts for Process Control

In spite of the excellent state of control shown by the green-thickness control chart in Figure 3, it is a fact that thickness charts do go out of control sometimes. When this happens a search for the assignable cause is made in cooperation with the operator. Prompt detection, identification, and elimination of these assignable causes as soon as they appear results in good thickness control. Assignable causes such charts generally catch are: wrong lathe set up, loose machine parts, cutting cold logs, or not using large enough chucks when needed.

Figure 4 shows a control chart kept on moisture content of 1/28 rift oak veneer as it emerged from a veneer drier.

The out of control condition shown in the first part of the chart indicated

[4] Grant, E. L. 1946. "Statistical Quality Control", pp. 537. McGraw-Hill Book Company, Inc., New York, N. Y. 1st Ed.

FIGURE 5

QUALITY CONTROL

CHARACTERISTIC MEASURED- DRY CLIPPING WASTE (1/20 ROTARY CUT BIRCH VENEER)

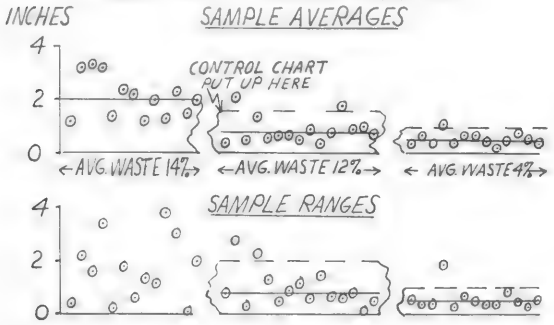
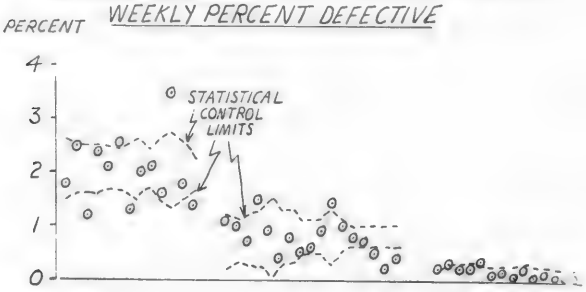


FIGURE 6

QUALITY CONTROL

CHARACTERISTIC MEASURED- PANELS SANDED THROUGH



there was excess variation in moisture content between flitches due to the presence of assignable causes.

From past experience we know that the reason for unusual variation in moisture content between flitches can be grouped into two categories. One category includes unusual variation in basic properties of the raw material itself which have an influence on drying such as green moisture content, specific gravity, width, or thickness. The second category includes variables of drier operation such as speeds, temperatures, circulation, and pressures. The factors in the first category are subject to a lesser degree of control and compensation because of materials handling consideration than is true of those in the second category.

When the control chart for averages goes out of control most of the time we have found the causes in the second category responsible, so we concentrate our trouble-shooting effort there. When assignable causes in the second category cannot be found it is concluded that the out of control condition is probably caused by unusual variation in one or more causes in the first category and the drier controls are not changed. This procedure tends to reduce the undesirable practice of machine "over-adjustment" which in many cases actually adds to the overall variability.

In Figure 4 almost all of the out of control points could be traced to differences between the three shifts in speed-temperature-setup combinations used to dry the same material. Although it is true that there was more than one speed-temperature combination which would give the desired average moisture of 15 percent, some of the different combinations used would not do so.

When this situation was pointed out to Production Management, they requested the Quality Control Department to make out standard set-up charts for all drier foremen.

Using multiple correlation methods these set-up charts were worked out showing the proper speed to use over a range of temperatures to give a constant desired average outgoing moisture content for all species.

The drier foremen were instructed in the use of the set-up chart, and the resulting improvement in control of moisture is shown on the last part of the chart once the assignable cause of lack of standardization in set-up technique had been discovered and eliminated.

Use of Statistical Control Charts for Waste Control

The control of waste is of vital importance in the quality-cost ratio. This is especially true of the woodworking industry for two reasons. First the raw material cost is a relatively large part of the total cost of production. Second, in spite of increasingly efficient utilization methods, the total material waste from raw material to finished product is still quite high.

Figure 5 shows the control chart method used to investigate the trimming waste resulting from reclipping 1/20 rotary-cut birch veneer we purchased from an outside source. This re-clipping procedure was felt necessary in order to eliminate tapered pieces, and to clip out occasional defects to upgrade the veneer. It was recognized that some trim waste was inevitable in this operation, but the question was whether the present waste was excessive.

The trim waste was measured on 3 waste pieces taken at random from the waste box under the clipper. After taking the measurements the quality control inspector plotted the results on the control chart hanging in full view of the clipper operator.

A rather striking decrease in the amount of trim waste was realized soon after the chart was put up. The psychological effect of a publicly displayed control chart plus standardization of clipping procedures resulted in a marked decrease in trim waste. The chart shows the average waste per piece was reduced from an initial average of 2 inches down to a final average of about 1/2 inch where a good state of control was obtained. Considering the width of the average piece this decrease in waste expressed as a percent went from 14 percent down to 4 percent. Since the material was very expensive and since we had a high volume operation this waste reduction effected a savings in dollars which was quite substantial.

Similar waste control charts are kept on other clippers, and also in the flooring mill to control unnecessary waste realized by sawing out knots and other defects from the lumber from which flooring is made.

Use of Statistical Control Charts for Scrap Control

Scrap control in addition to process control and waste control also has an important influence on the quality-cost ratio in any industry.

An example of how a control chart can be used effectively in scrap control is shown in Figure 6. This is a control chart on weekly percent seriously defective plywood panels due to "edges sanded through". This percent defective chart is a little different from the control charts previously shown in that the quality variation here is measured by attributes rather than by variables. Formulas for the calculation of control limits are different. Because in this case the sample size varies the control limits vary also.

The chart shows a substantial reduction in percent defective over a 3-year period resulting from detection and elimination of assignable causes from time to time. The two things mainly responsible for this improvement were better control of the plywood sander machine, and also the separation all through plywood manufacture of the "round-up" veneer from the rest of

the veneer. Thickness control charts had shown that when out of control points were obtained that most came from the veneer cut from the outer part of the log in the first couple of turns on the lathe. This was due to the fact that the outer layer still often contained some rough spots from the debarking operation. Another reason for unusual thickness variation in the first few turns was that the log was not generally a perfect cylinder when first put on the lathe.

Even though the volume of the round-up veneer was small, the harmful effect of its excess thickness variation would be magnified if it were allowed to be mixed with the veneer from the rest of the log. It only takes one excessively thick or thin piece to cause the panel to show a defect due to "sand through" or "glue not sticking."

The separation of round up veneer and its use in low grade panels only was one of the main reasons for the decrease in percent defective shown in Figure 6. This was a case where the assignable cause though not eliminated was at least compensated for.

Similar control charts are also kept on other plywood defects. Control charts on weekly total percent seriously defective, and on weekly scrap cost per thousand square feet are a part of Quality Control's weekly plywood report to Managament. The heart of this program of scrap control is the weekly plywood defect data sheet shown in Figure 7. With the serious defects cross classified by type and source as shown, the identification and elimination of assignable causes indicated on the control charts is greatly expedited.

Records indicate that the results of this control chart approach to scrap control has resulted in a reduction in percent seriously defective to less than a third of what was being obtained some years ago when statistical quality control was first put to work on the scrap pile.

Our percent seriously defective plywood panels is currently controlled at about a 3 percent average level which we feel is a low or lower than other comparable plywood plants.

Considering the magnitude of the weekly scrap cost total shown in Figure 7 such a reduction in defectives through the combined efforts of Quality Control and Production also meant a substantial dollar saving, and a further improvement in the quality-cost ratio.

Important By-Products of Control Charts

In previous examples, we have seen how the achievement of a state of statistical control generally results in a substantial improvement in the quality-cost ratio. However, the benefits of achieving a state of statistical control are not limited to this alone. Many times further improvements and cost savings can be made by changes you can make in a controlled process which are not possible until control is obtained.

Figure 8 shows a control chart on the dry thickness of 1/28 inch Philippine mahogany veneers, showing an excellent state of control about an average level of .038 inch. But 1/28-inch is equal to .0357 inch. This raised the question of what do you mean when you say you are cutting 1/28-inch veneer. Does it mean the average should be 1/28 or .0357 or does it mean that the .0357 value should be the minimum thickness. Different people had different ideas about it. The majority thought it would be better to be on the safe side, and cut the veneer so none would be below the nominal 1/28 inch. Plywood panels made from the veneer would have less chance of sanding through or coming out thin, they said.

A frequency distribution comparison of 1/28-inch veneer we cut to 1/28-inch veneer we bought showed our

QUALITY CONTROL FIGURE 7

PLYWOOD DEFECT DATA SHEET

PROBABLE SOURCE OF DEFECTS — DATE

TYPES OF DEFECTS

	VENEER CUTTING	DRYER	JOINTING	SPLICEING	CLIPPING	VENEER GRADING	SPREADING	LAYUP	PRESSING	SAWING	SANDING	HANDLING	SCARFING	NOT EVIDENT	MISC. DEFECTS	TOTAL	SCRAP COST
	1	2	3	4	5	6	7	8	9	10	11	12	13	14 15 16			
1														1		1	$5.12
2																	
3								1			12	6		5		24	52.59
4						2				1				6		9	15.44
5								9								9	22.09
6	2													5		7	5.09
7								4								4	1.69
8																	
9						6										6	10.32
10														9		9	11.54
11						8										8	27.81
12								3								3	3.32
13			17					6						10		33	56.77
14																	
15														5		5	2.84
16	13															13	35.49
17									6					44		51	39.52
18										1		5		2		8	17.42
19										3						3	3.92
20	2										3			3		8	17.48
21				2	1					5				16		24	22.24
22				1										1		2	5.06
23				10	3	1		5						20		39	44.59
24														11		12	1.16
25								9								9	12.43
26			9			2								1		12	43.64
27			11			1		1						6		19	16.86
28														6		6	20.43
29											3					3	10.24
30	1															1	3.02
31																	
32																	
33					5											5	15.20
34						2		7								9	13.96
35																	
	18		38	13	9			46	6	10	18	11		151		342	$537.31
	$50.42		103.47	16.14	6.30	69.28		51.57	6.77	22.34	54.90	14.15		126.77	$37.31		

TOTAL FOOTAGE GRADED 228,096

TOTAL DEFECTIVE FOOTAGE

PERCENT DEFECTIVE FOOTAGE

SCRAP COST PER. 1000 SQ. FT. $2.37

% SERIOUS DEFECTIVE PANELS 2.1%

Defect seen: 1, Blown; 2, bleed through; 3, broken; 4, dents; 5, gap in core; 6, glue didn't stick; 7, glue pressed in face; 8, glue on splicer line; 9, hole in core; 10, hole in face; 11, knots; 12, overlap core; 13, overlap face; 14, overlap crossband; 15, oil and grease stain; 16, not cleaned up; 17, piece out of face; 18, piece out of side; 19, rubber; 20, sanded through; 21, short core; 22, short back; 23, short face; 24, short crossband; 25, slivers pressed in wood; 26, splits center; 27, splits end; 28, stained wood; 29, stopped in sander; 30, rubber; 31, tape; 32, warped; 33, worm holes.

FIGURE 8

QUALITY CONTROL

CHARACTERISTIC MEASURED- DRY THICKNESS
(1/28 SLICED PHILIPPINE MAHOGANY)
SAMPLE AVERAGES

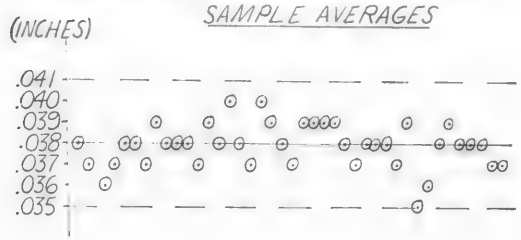
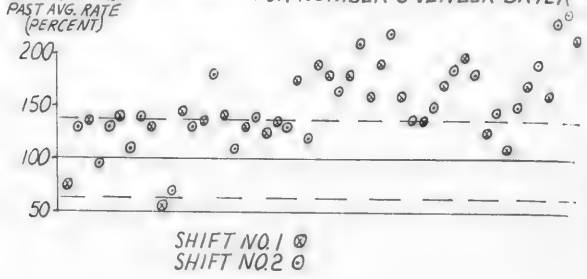


FIGURE 9

QUALITY CONTROL

CHARACTERISTIC MEASURED- PRODUCTION RATE DEVIATION FOR NUMBER 3 VENEER DRYER



SHIFT NO. 1 ⊗
SHIFT NO. 2 ⊙

suppliers were cutting their veneer to average the nominal thickness, whereas we were cutting ours so the minimum was the nominal. Further, an examination of the daily plywood defect data sheets kept by Quality Control showed no difference in the number of sand throughs of panels where face veneers were bought as 1/28 veneer compared to those where face veneers were 1/28 we cut ourselves. Also the fact that we had gained a state of statistical control meant that in the long run over 95 per cent of the veneer we cut would not contain pieces any thinner than .033 inch if we set our average at the .036-inch nominal. Such a reduction in average thickness would also mean a yield increase of over 5 percent of this very valuable face veneer material.

When all these facts were pointed out to Production they agreed there was really no reason why we could not cut all our 1/28-inch veneer to average the nominal thickness as was being done by our suppliers, and orders were issued to make this process change.

Another interesting control chart by-product development concerned the waste control chart previously referred to in Figure 5.

As a result of the analysis of data taken to plot the waste control chart this interesting question was raised. Was it really necessary to reclip all the purchased veneer as was being done?

Frequency distribution comparison between original taper present before reclipping to final taper present after reclipping showed that although a general reduction in taper was obtained, it was by no means completely eliminated. This might mean that the taper of each piece clipped had been reduced by some amount less than 100 percent. Or it might mean in some pieces the taper was decreased while in others it was not. Perhaps, the clipping operation even added to the original taper present for certain pieces. If this were true we would be wasting both labor and material unnecessarily.

Using another statistical quality control technique called linear correlation, the answer to this question was obtained. From this study it was found that we were indeed not gaining anything in trying to reclip certain pieces. In fact the analysis showed that the inherent process capability of the clipping operation itself, even though performing at its best, was such that little taper reduction was obtained by reclipping pieces which had original taper in the amount lass than 1/4 inch.

Accordingly Quality Control's recommendations to Production was to construct a special measuring board which would rapidly measure taper, and to pass on without reclipping all pieces containing 1/4 inch or less original taper. This was done and as a result only about half of the veneer had to be reclipped whereas formerly all had been. A further waste reduction was therefore made above and beyond the one realized through the direct effect of the control chart in decreasing waste on pieces which were clipped.

The veneer moisture control chart shown in Figure 4 also had some useful by-product advantages connected with it. As a result of analysis of data contained in the quality control data sheet from which the moisture control chart was plotted, it was revealed that in some cases not only were the speed-temperature combinations wrong from the standpoint of obtaining desired average moisture content; in many cases they were not the best ones for obtaining the maximum production rates for the drier. These settings for maximum production rates were the ones at which the proper speed was used to dry the veneer to the desired average moisture with the drier temperatures set as high as the veneer could stand without excess splitting or buckling. Higher temperature permitted faster speeds. The particular speed-temperature settings recommended for maximum production rates were calculated and incorporated into the previously mentioned standard set-up charts.

Use of these recommended settings by the drier foreman resulted in a substantial increase in production rate which averaged about 20 percent for all veneer categories in general and in some individual cases over 50 percent increase.

This resulted in a substantial savings in labor cost and afforded a marked decrease in the overtime at time-and-a-half rates which formerly was required to enable the driers to keep the plywood press supplied.

Another improvement which could be traced to the influence of the moisture control chart was the changing of the speed drive on one of the driers. Quality Control pointed out to Production that it would be possible to increase the heat on the thin veneers up to the maximum, and still get the desired moisture content if the drier could be run faster than the fastest speed currently obtainable. Analysis of the information contained on the quality control data sheet showed that the saving in labor cost resulting in such a change would pay for the cost of installing new speed gears inside of a 6-months period.

Figure 9 which is a control chart on the production rate of this drier shows the resulting improvement made for the 1/28 inch veneers. The control chart is out of control on the side of increased production due to carrying out the recommended design change. Control limits based on normal variation about the old production rate standards need to be revised and based on the new standards now obtainable.

Summary

Under today's competitive industrial conditions an alert management can not afford to overlook any methods which can help make the products of their industry more competitive.

The techniques of statistical quality control have proved capable of making a significant contribution to this effort in a wide variety of industries by improving the quality-cost ratio. The foregoing illustrations show how the same thing could be done in the woodworking industry if these modern quality control techniques were more widely used.

This advertisement appeared in the
May 15th issue of Business Week

Why this giant pipe is made of wood

This 60" all-wood pipe now conveys highly corrosive waste liquor from a pulp mill to a disposal area. The pipe line runs above ground, underground and, in one area, 15 feet below a river bed!

The pipe had to be strong, waterproof, acid-resistant and flexible enough to conform to uneven terrain. Treated wood did the job! The laminated wood hoops, tested to outward pressures of 78,000 lbs., were glued with CASCOPHEN, Borden's waterproof resorcin resin glue.

When you need a material to stand weathering, water, mold—as well as acids and alkalies—see a good engineer in wood . . . and see Borden's to insure proper gluing. Address: The Borden Company, Chemical Division, Department BW-54, 350 Madison Avenue, New York 17, N. Y.

ADHESIVES * CASEIN * INDUSTRIAL CHEMICALS
RESINS * POLYMERS * MOLDING COMPOUNDS

THE Borden COMPANY
CHEMICAL DIVISION

One of a series of advertisements appearing in several national magazines in the interest of better public understanding of tree farming and the forest products industry.

CHICKAREE in stand of 50 to 60 year old second growth on a Douglas fir tree farm. The dense forest has been marked for thinning. This will improve the quantity and quality of the tree crop

tree farmers work in partnership with nature...

Many useful woods for the modern homes of today and tomorrow will always come from America's tree farms. In the room below, wood affords warmth and beauty.

Industrial forestlands of America are one of the nation's most valuable natural resources. Every day, wood from these forests is used to build homes, make pulp and paper, chemicals and many other products. Today, men and nature are working together on tree farms to provide a continuing supply of wood for the future. As virgin old-growth timber is harvested for immediate use, it is being replaced by nature with stands of young trees. These new forest crops must be protected from fire, insects and disease until they are ready for harvesting.

Tree farmers are also working to improve the quality and quantity of these future timber crops. Selective thinning of dense young fir stands improves the growth rate and wood quality of the trees left. Trees cut supply good wood normally lost through competition for growing space.

A perpetual wood supply is the goal of more than 4,800 private owners of about 30 million acres of industrial forestland. All timberlands owned by Weyerhaeuser Timber Company are managed as tree farms. *Write us at Box A, Tacoma, Washington for a free copy of our colorful and interesting booklet,* ***Tree Farming in the Pacific Northwest.***

Weyerhaeuser Timber Company

WEYERHAEUSER
4-SQUARE

1954 National Meeting

(Continued from page 15-A)

Jack Koellisch, manager, Wood & Wood Products Magazine, presents awards to E. L. Ellis for U. of Idaho winners, and Charles Morschauser, graduate winner.

Receiving Woodworking Digest awards are, l. to r., John Reno, Mrs. E. Russert, R. C. VanKampen, the publisher, and Ted Connelly. Other winners in background.

and Wood Products magazine, donor of the awards. Charles R. Morschauser, University of Michigan, won the graduate division certificate and cash award of $350 for his paper on "Effect of Rays on Shrinkage of Red Oak." (See page 280). Co-authors Robert H McAlister and Robert L. Myers, University of Idaho seniors, received their certificates and split the undergraduate cash award of $150 for collaborating on "The Accuracy of an Electric Moisture Detector in Determining the Moisture Content of Living Trees."

The first annual "Award of Merit" citation was presented to three trade associations and five firms in the wood products field, "In recognition of the assistance which each organization gave in advancing public understanding of the advantages, values, and uses of wood over other materials." The citations were presented by the publisher of Woodworking Digest to The Hardwood Exhibit, Inc.; West Coast Lumbermen's Association; National Wood Office Furniture Institute; The Pacific Lumber Co.; Kingsford Chemical Co.; E. L. Bruce Co.; DeWalt, Inc.; and The Borden Co. Mr. Robert C. Van Kampen, president of the Hitchcock Publishing Co., presented the awards at the official FPRS Luncheon, Wednesday noon.

Pres. Pauley Opens Technical Sessions

The Official Technical Sessions of the eighth national meeting were opened on Thursday morning by the 1954 FPRS President Robert D. Pauley, Weyerhaeuser Timber Co., Tacoma, Wash., under the technical program direction of Lester J. Carr, L. J. Carr & Co., Sacramento, Calif., incoming 1955 FPRS President. On Thursday some 22 papers covering packaging, wood composition board, wood machining, and wood drying were presented.

At the 8th Annual Business Meeting, Thursday forenoon, newly-elected officers, board members, and nominating committee for 1955 were announced by the Chairman of the Tellers Committee, Kenneth G. Chesley, Crossett Lumber Co., Crossett, Ark.

Incoming president L. J. Carr gives outgoing president Bob Pauley "shotgun" reception.

New Officers and Board Members Announced

Lester J. Carr automatically succeeded to the presidency of FPRS. Elected to the office of President-Elect was M. B. Christian, Director of Research, Chicago Mill & Lumber Co., Tallulah, La. Elected Vice-President was Ralph H. Bescher, District Manager of Sales and Operation, Wood Preserving Division, Koppers Co., Inc., Pittsburgh, Pa. Elected Northwest Regional Board Member was John D. Ritchie, Allied Products Director, Douglas Fir Plywood Association, Tacoma, Washington. Elected Northeast Regional Board Member was Frank T. Parrish, Experimental and Development Manager, Heywood–Wakefield Co., Gardner, Mass. Elected to serve on the 1955 National Nominating Committee were: Arthur B. Anderson, University of California School of Forestry, Berkeley, Calif.; George G. Marra, Division of Industrial Research, Washington State Institute of Technology, Pullman, Wash.; Herbert B. McKean, Director of Research, Potlatch Forests, Inc., Lewiston, Idaho; and Frederick F. Wangaard, Professor, Yale School of Forestry, New Haven, Conn.

Thursday noon in the Hotel Pantlind the Section Officers Advisory Committee and Executive Board held their annual joint luncheon and meeting. Student member benefits, cross-indexing of the FPRS Journal, a unified Section accounting system, release of details on the plans for the executive office building, periodic charted reports to Sections, clearance of proposed Section meeting dates through Executive Office, Supporting Member privileges, and other items were discussed.

Thursday evening over one thousand persons filled every available meeting room of the Hotel Pantlind for the traditional FPRS Suppliers "Paul Bunyan Hour". The Hour this year was again sponsored by over 60 suppliers to the forest products industry. Following the Paul Bunyan Hour an estimated 500 persons attended the annual "FPRS Party" in the Civic Auditorium. Every available place was taken and many persons had reluctantly to be turned away at the last moment. Paul Bunyan Hour sponsors this year included:

The Louis Allis Co., Milwaukee, Wis.

American Cyanamid Co., New York, N. Y.

Aries Fiberboard Corp., New York, N. Y.

The Bahnson Co., Winston–Salem, N. C.

The Black Bros. Co., Mendota, Ill.

The Borden Co., New York, N. Y.

Buss Machine Works, Holland, Mich.

1954 "Paul Bunyan Hour" Sponsors

(Continued from page 23-A)

The Carborundum Co., Niagara Falls, N. Y.

The Coe Manufacturing Co., Painesville, Ohio

Clark Equipment Co., Battle Creek, Mich.

Cleworth Publishing Co., Battle Creek, Mich.

Drake Corp., St. Louis, Mo.

Moore Dry Kiln Co., Jacksonville, Fla.

The Dow Chemical Co., Midland, Mich.

J. A. Fay & Egan Co., Cincinnati, Ohio

Fjellman & Winther Co., Joliet, Ill.

Greenlee Bros. & Co., Rockford, Ill.

Hermance Machine Co., Williamsport, Pa.

Hiller & Stuart Co., Grand Rapids, Mich.

Hitchcock Publishing Co., Wheaton, Ill.

Irvington Machine Works, Portland, Ore.

James T. Donnolly Co., Ltd., Toronto, Canada

Curt G. Joa, Inc., Sheboygan Falls, Wis.

Jones Superior Machine Co., Chicago, Ill.

Kennametal, Inc., Latrobe, Pa.

Kirk & Blum Manufacturing Co., Cincinnati, Ohio

Mann–Russell Electronics, Tacoma, Wash.

C. K. L. Machinery Co., Oshkosh, Wis.

Masonite Corp., Chicago, Ill.

Mattison Machine Works, Rockford, Ill.

Mereen–Johnson Machine Co., Minneapolis, Minn.

Merritt–Solem Corp., Lockport N. Y.

Moisture Register Co., Alhambra Calif.

Monsanto Chemical Co., St. Louis Mo.

Monical Machine Co., Grand Rapids Mich.

National Casein Co., Chicago, Ill.

Nelsonite Chemical Products, Inc Grand Rapids, Mich.

Newman Machine Co., Inc., Greensboro, N. C.

Oliver Machinery Co., Grand Rapids, Mich.

Onsrud Machine Works, Inc., Chicago, Ill.

The Pacific Lumber Co., Scotia Calif.

Perkins Glue Co., Lansdale, Pa.

Powers Wire Products Co., Monroe Mich.

Protection Products Mfg. Co., Kalamazoo, Mich.

Red Lion Cabinet Co., Red Lion, Pa

Reichhold Chemicals, Inc., White Plains, N. Y.

Rockwell Mfg. Co., Pittsburgh, Pa

Rohm & Haas Co., Philadelphia, Pa.

B. M. Root Co., York, Pa.

Sheboygan Machine Co., Sheboygan, Wis.

Simonds Saw & Steel Co. Fitchburg, Mass.

The S. H. Smith Co., Indianapolis, Ind.

Southern Lumberman, Nashville Tenn.

Stetson–Ross Machine Co., Seattle Wash.

The Tannewitz Works, Grand Rapids, Mich.

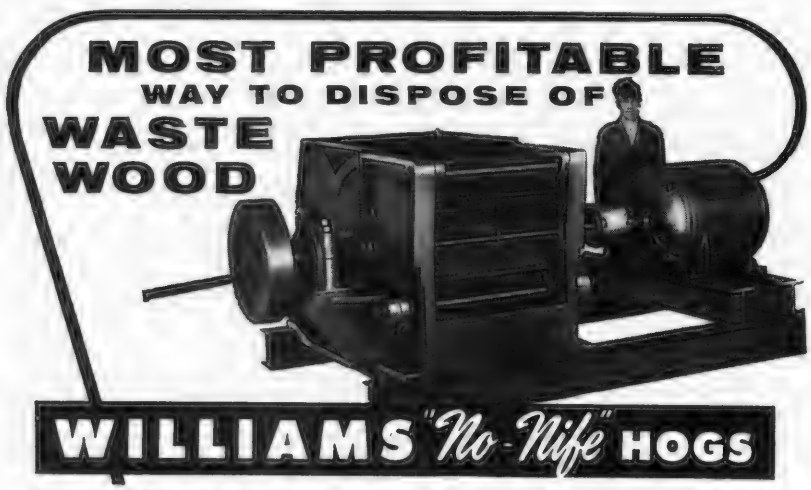
Union Tool Corp., Warsaw, Ind.

Wolverine Finishes Corp., Grand Rapids, Mich.

Baxter D. Whitney & Son, Inc Winchendon, Mass.

The Williams Patent Crusher & Pulverizer Co., St. Louis, Mo.

Yates–American Machine Co Beloit, Wis.



BIG MARKET FOR GROUND WOOD. Chip board and many other ground wood products offer a tremendous market for waste wood—but manufacturers of these products demand uniformity in quality and size—requirements that Williams hogs are fulfilling in dozens of plants. Whether the wood scrap you sell is in chips, sawdust or flour, a Williams will produce more, faster, with less labor, power and upkeep.

BIG INCREASE IN HEAT VALUE. Wood waste for fuel yields more heat when hogged in a Williams for uniform, complete combustion. Unhogged wood restricts air flow, smothers the fire, burns unevenly, creates excessive smoke. Williams equipment also reduces handling costs as much as 75%! When hogged, one man can handle as much as three men can handle in long, cumbersome pieces.

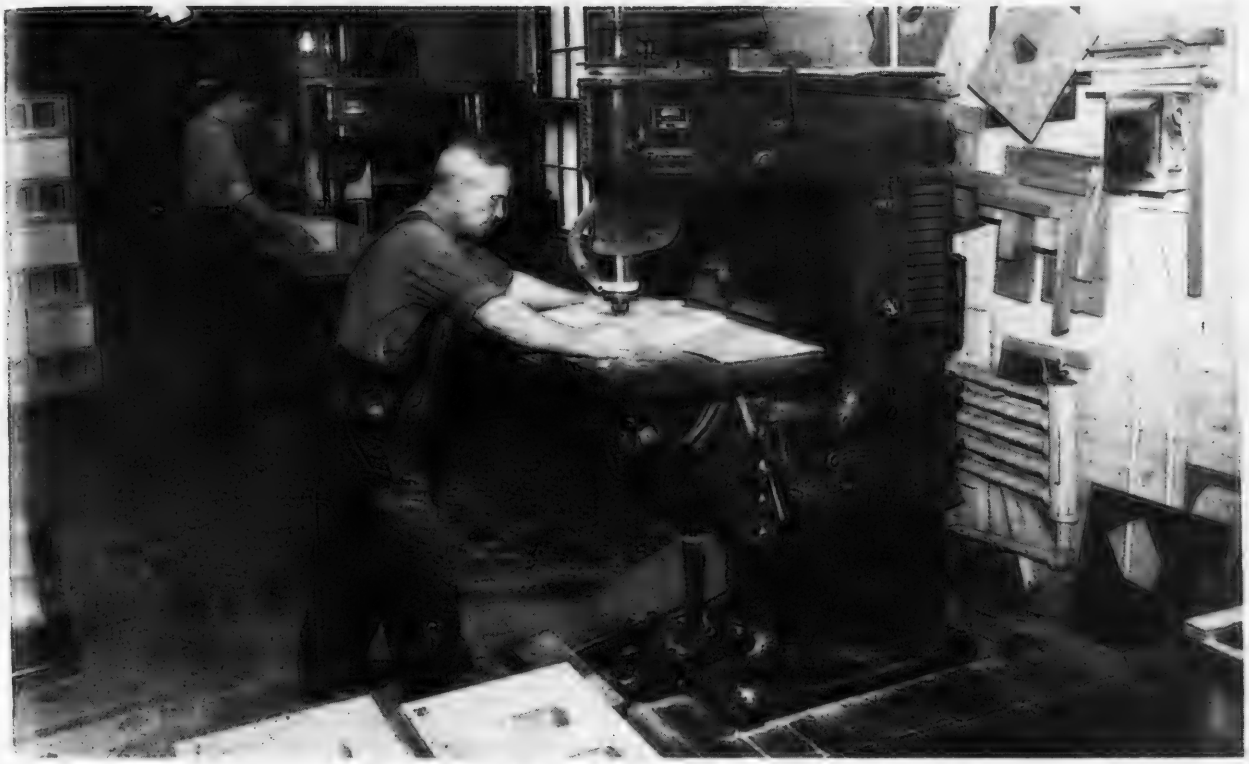
WILLIAMS AUTOMATIC INSTALLATIONS EARN PHENOMENAL PROFITS when used for hogging and conveying wood waste to boiler or stoker—or for grinding, separating and packaging ground and sized wood.

Write for Illustrated Brochure

WILLIAMS BUILDS A COMPLETE LINE
• Hogging, Grinding and Shredding Machines
• Vibrating Screens • Air Separators • Conveying Systems
• Cyclone Collectors • Complete "Packaged" Plants

WILLIAMS PATENT CRUSHER & PULVERIZER CO.
2714 N. Ninth St.
St. Louis 6, Mo.

WILLIAMS
CRUSHERS GRINDERS SHREDDERS
OLDEST AND LARGEST MANUFACTURER OF HAMMER MILLS IN THE WORLD



consistently high speed production . . .

with Onsrud routers and shapers

PORTABLE ROUTERS

Onsrud precision woodworking machines turn out work at high production speed, yet maintain accuracy equal to the pattern on every part produced.

Their ability to perform so fast and so efficiently on any production job is the result of outstanding design and careful workmanship incorporated into every Onsrud machine assembly. Combined with a host of operating features that make set-up and operation simple and easy, these machines pay their way over and over again in any shop.

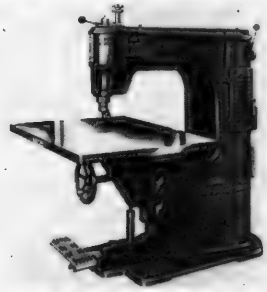
Design features including unusually high spindle speed, spindle vacuum pulley, automatic belt tension, two speed motors, and life lubricated bearings make Onsrud machines the leaders in their respective fields.

These facts are important today because competition within, as well as outside of the woodworking industry, calls for the use of every technique that will increase production and keep costs down. Call or write for more information on the complete Onsrud line, for lowering production costs . . . now.

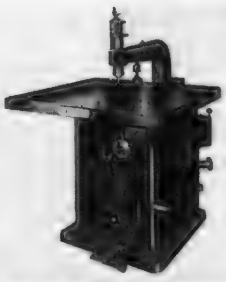
ONSRUD MACHINE WORKS, INC.

3954 WEST PALMER STREET CHICAGO 47, ILLINOIS

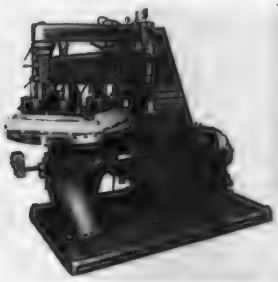
W-180 MEDIUM DUTY ROUTER



W-244 HEAVY DUTY ROUTER



W-250 HEAVY DUTY SHAPER



WA-50 AUTOMATIC SHAPER

The Woodworkers' Industry Show running from 9:00 a.m. to 9:00 p.m. and the FPRS technical sessions dominated the final day of the meeting. Sessions V and VI in the morning had twelve papers presented on glues and gluing, and general subjects. Sessions VII and VIII covering wood finishing and quality control included ten papers on their programs.

Employment Service

The informal FPRS employment service at the meeting was conducted by Prof. Newell A. Norton, Professor of Wood Utilization, Pennsylvania State College, State College, Pa., from nine to eleven Thursday and Friday mornings. Five positions were listed by companies seeking employees and eleven applicants sought positions.

Outstanding Ladies Program

Seventy-seven wives of FPRS members and guests registered for the Ladies' Program which started Tuesday evening, May 4th, at 8:00 p.m. with humorous readings and character sketches by Miss Nancy Blue. This informal coffee hour gave the wives of FPRS members an opportunity to meet some of the women community leaders in Grand Rapids.

National Meeting Chairman Fred Dickinson names those who worked hard to make meeting a success.

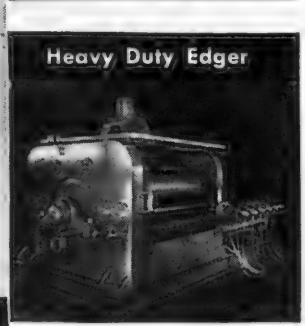
Wednesday, May 5, at 11:00 a.m. the women enjoyed a brunch in the Continental Room of the Hotel Pantlind. Mrs. Paul G. Goebel, noted Michigan columnist, lecturer, and wife of the former mayor of Grand Rapids, presented her thoughts on "Women In Government." At 2:00 p.m. a tour of the Johnson Furniture Exhibit Rooms was conducted with a commentary by designer Renzo R. Rutilli.

Thursday, May 6, the women enjoyed the day visiting the Widdicomb Show Room, The Guild, The Baker Exhibit, and the Stow–Davis furniture showrooms. At 5:30 p.m. the Paul Bunyan Cocktail Hour was sponsored for the pleasure of FPRS members, wives, and guests. The women joined their husbands at the FPRS Party and Banquet that evening. Particularly interesting were the many door prizes arranged for by Mrs. Lillie and offered by Grand Rapids manufacturers which generally included items of furniture. Dancing in the Moca Room of the Hotel Pantlind followed the Party.

The ladies went to Holland, Michigan the final day of the meeting where they visited the Baker Museum of antique furniture, the Netherlands Museum, and viewed the famous Holland tulip gardens in full bloom. They enjoyed a luncheon at the Warm Friend Tavern and returned via the Lake Shore Drive in the afternoon.

1954 National Meeting Committee Deserve Big Hand

Here they are: Fred Dickinson, Chairman; Steve Pryce, Arrangements; George Herrity, Publicity; Steve Preston, Finance; Helen Gleason, Ladies' program; George Meier and Virl Marshall, Signs; Bob Milham, plant tours; Vic Barnes, Sam Tamminga, Duane Kenaga, Herf Garland, John McPhee, Bill Martin, Bert Baker, Wayne Hutchins and all of the official hosts; and finally, Mrs. Pryce and Mrs. Lillie, who so ably assisted Helen Gleason, and Mmes. Dickinson, Preston and all the ladies who participated in the ladies' program. Congratulations to you all for a fine job.



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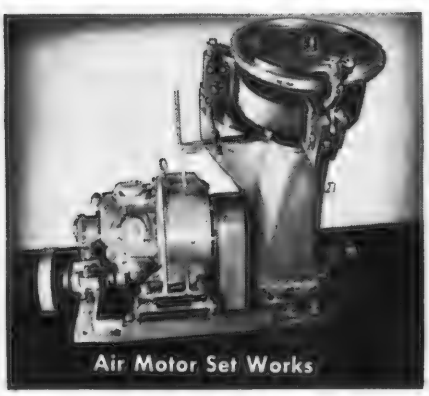
BUILDERS OF A COMPLETE LINE OF SAWMILL MACHINERY SINCE 1856



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Exclusive Kirk & Blum Plenum Main Systems in large North Eastern Toy Manufacturing Plant.

For 47 years, Kirk & Blum has specialized in the DESIGN, FABRICATION and INSTALLATION of efficient, dependable systems for the removal of dust and fumes.

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CONSTRUCTION: Kirk & Blum fabricates the complete system (equipment excepted), "tailor made" for your installation.

INSTALLATION: The Kirk & Blum contract includes responsibility for the entire system, installed by mechanics with years of specialized experience in the installation of such systems.

• **As a result, you have one undivided responsibility—*one complete contract for an installed system, ready to operate.*** **The Kirk & Blum Mfg. Co., 3231 Forrer St., Cincinnati 9, Ohio**

Dust Collecting Systems at American Mfg. Concern, Falconer, N. Y.

FOR CLEAN AIR . . . THE INVISIBLE *TOOL*

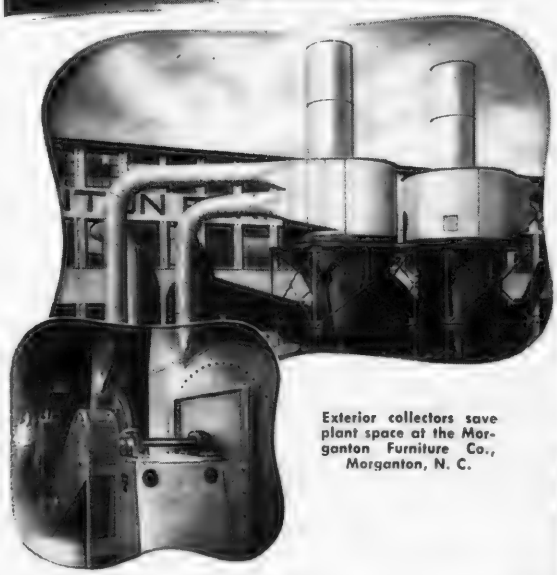
KIRK AND BLUM

DUST & FUME CONTROL SYSTEMS

WRITE FOR ANY OF THE FOLLOWING BOOKLETS:

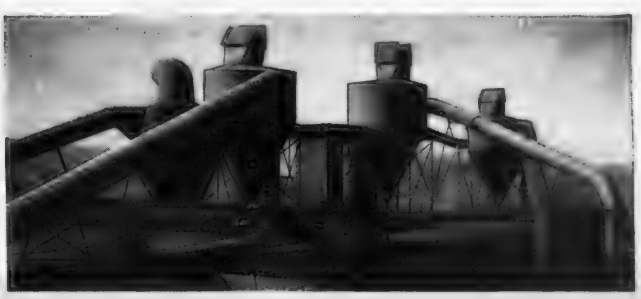
"Blower Systems for Woodworking Plants"
"Fan Systems for Various Industries"

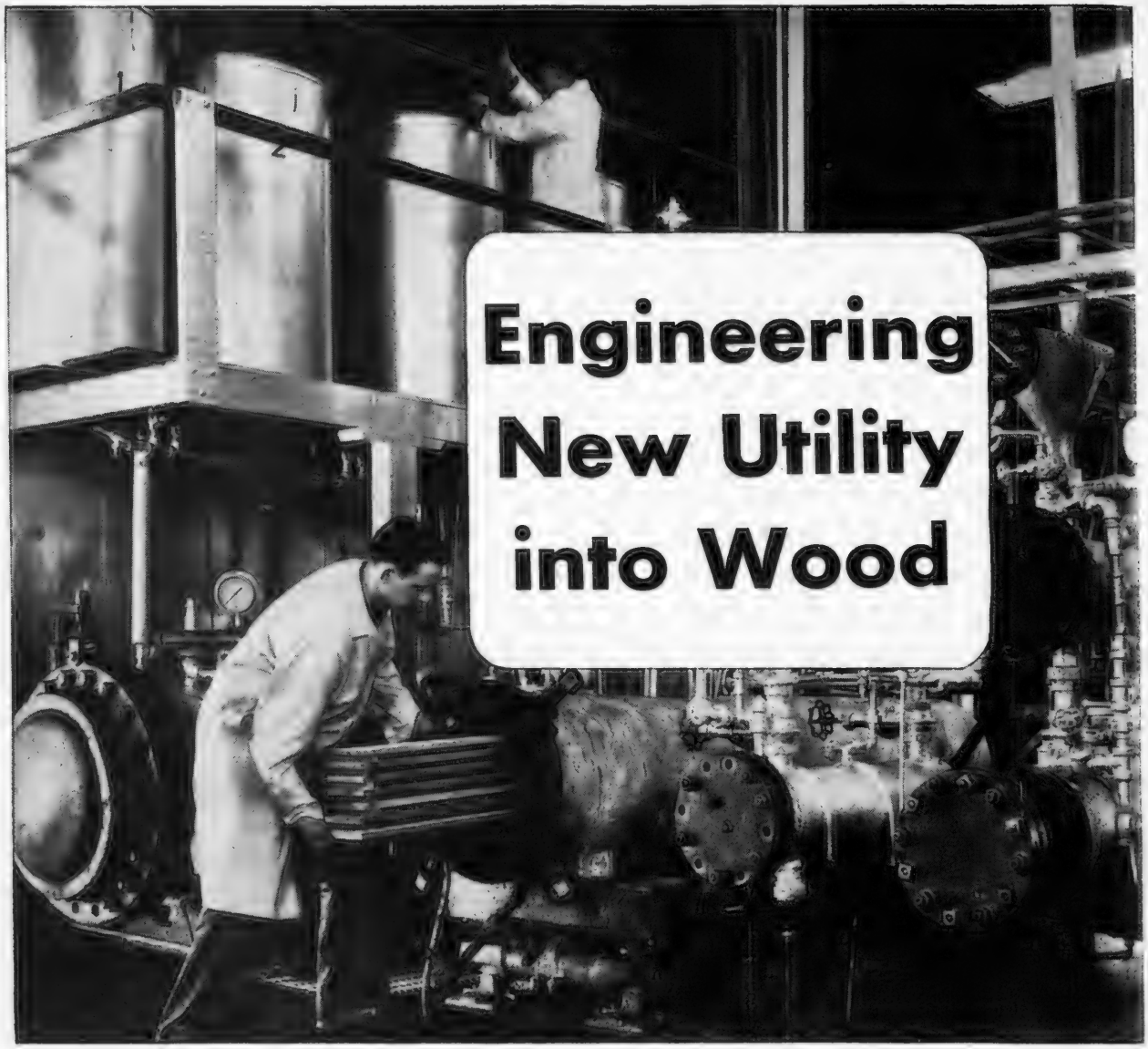
K & B streamlined Tapered Main System for the Sports Products Co., Cincinnati, Ohio.



Exterior collectors save plant space at the Morganton Furniture Co., Morganton, N. C.

This cluster of Cyclones collects sawdust, shavings and chips at the Bernhardt Furniture Co., Lenoir, N. C.





Engineering New Utility into Wood

at the Koppers Technical Laboratory

• Koppers pressure-treated wood products have proved their worth by giving customers long and satisfactory service. But Koppers doesn't rest on its laurels. At its Technical Laboratory in Orrville, Ohio, Koppers works to improve its products so that they will do an even better job.

Here, in one of the most complete and best equipped wood-treating laboratories in the world, Koppers technicians conduct exhaustive tests on the prevention of wood deterioration.

A man-made "tropical jungle" accelerates the rate of decay in wood and thus provides samplings for study. Impact-testing machines determine the loss of strength caused by the various agents that attack wood. There is a battery of pressure cylinders for impregnating wood with various preservatives and for testing all known treating procedures.

This continuing program of research is another way in which Koppers is hard at work to make wood serve industry better and more economically.

KOPPERS COMPANY, INC.

KOPPERS

PRESSURE-TREATED WOOD

Wood Preserving Division, Pittsburgh 19, Pennsylvania

Report of FPRS 1954 Annual Business Meeting

THE EIGHTH ANNUAL business meeting, held in the Red and Gold Room of the Civic Auditorium, Grand Rapids, was called to order by president Robert D. Pauley, at 11:30 a.m., Thursday, May 6, 1954. Some 75 members were in attendance.

John Ritchie invites members to '55 annual meeting in Seattle.

1. Minutes of Previous Meeting

The preceding annual business meeting was held in Memphis, Tennessee, June 15, 1953; and the minutes were published in the December Journal, FPRS. No corrections or additions having been offered, it was duly moved, seconded and passed that they be accepted.

2. Annual Report of Executive Secretary

During fiscal year 1954, ending March 31, 1954, FPRS' net membership was increased from 2,284 to 2,634 members or 15.3 per cent. Since March 31, we have added 51 new members bringing the total to 2,683 members as we convene here in Grand Rapids. This is the highest, and I have been proud to make this assertion for three consecutive years, total in our history. We now have members in all 48 states, U. S. possessions, Canada, and most free nations of the world.

Financially, we started the fiscal year 1954 with a cash balance of $29,032, of which $6,088 was accumulated surplus for some needed future day. During the year our total receipts amounted to $74,836 and our total expenditures to $74,353 including $500 deposit on a piece of real estate for the proposed new office building. Accounts receivable amounted to $823, and accounts payable, to $72. Our cash balance as of April 1, 1954 amounted to $24,516 plus $5,000 in short term investment. Of this balance $20,100 was accounted for by pre-paid dues, and $7,119 as surplus. In other words, we added approximately $1,000 to our surplus in 1953.

Technical activities reached an all-time high in f.y. 1954. Particularly noteworthy has been the splendid activity of FPRS thirteen subject matter committees, and the continually improving content of the Journal, FPRS.

Members received more pages of information, of a better quality, than in the previous year. For the first time, the Journal was placed on a regular, every-other-month schedule.

Executive office work increases as our organization grows. The executive board authorized the addition of a full-time administrative assistant, bringing the total staff to five full-time and two part-time employes.

Twelve of our 13 sections in the U. S. and Canada held one or more meetings during the f.y. 1954. Twenty-three meetings were held in f.y. 1954 compared to 20 in f.y. 1953. The Pacific Northwest Section took the individual section lead this year by holding four meetings, followed by Northeast, Eastern Canadian and Pacific Southwest with three each. The accompanying table lists these meetings along with their principal features.

President Pauley was the guest of honor at a number of our meetings in the west, midwest and south. Unfortunately the press of business matters prevented him from attending several meetings he had scheduled in Canada and in the east. The executive secretary or staff attended meetings of the Ohio Valley, Midwest, Florida–Georgia–Alabama, and Upper Mississippi Valley sections.

The Seventh Annual Meeting of the Society held at the Peabody Hotel, Memphis, Tennessee, was a success. During two-and one-half days a total of 424 members and guests were registered.

Your hard-working executive board, the members of which are not personally reimbursed for their time, effort and expenses, rolled up their sleeves at two and three-day meetings on three occasions during the year: Memphis in June, Denver in September, and Madison this March. Major actions included a program of cooperation with the 1954 Woodworkers Industry Show, review and strengthening of executive office staff requirements, establishing of a permanent national office building of the Society in Madison, expansion of the Journal to six issues yearly, increase in student member services and expansion of subject matter committees.

Observed as a whole, FPRS has had another banner year under the fine leadership of executive board, section, and committee personnel backed by the solid support of an enthusiastic membership. We are growing and shall continue to grow more strongly each year.

3. Report of the Audit Committee

The committee consisting of Charles C. Thompson, Herbert O. Fleischer and George W. Johnson, Chairman, met with accountants Victor Hobert and Dan Richmond, and the executive secretary in Madison on April 30. It examined the records and reported that the balance sheet and operating statement, as shown separately, reflected a true summary of the financial transactions of the national organization for the year. It pointed out that the audit does not reflect the entire picture of the sections in relation to the national, and does not cover the finances of the sections. It recommended that counsel be obtained to determine legal relationship between national and sections with particular respect to financial liability, and that the By-laws be strengthened with respect to submission of section annual reports.

4. Report of Publications Committee

This committee, consisting of Eric A. Anderson, A. B. Anderson, E. A. Behr, J. S. Bethel, R. A. Cockrell, J. B. Grantham, M. S. Hudson, I. H. Isenberg, J. H. Tigelaar, F. F. Wangaard, Vice Chairman, and E. G. Locke, Chairman, reviewed its progress. The chairman discussed the establishment of the reviewing committee composed of some 100 authorities covering differ-

FPRS MEETINGS, FISCAL YEAR 1954

Date	Section or Event	Place	Subject
Mar. 5, 6	Eastern Canadian	Toronto, Ontario	Treating methods, waste utilization, veneer
Mar.	Northeast Extenion	Boston, Mass.	Wood trusses, beams, laminated structures
Apr. 16, 17	Ohio Valley	New Albany, Ind. & U. of Louisville	Seasoning, utilization, electronic gluing, finishing
Apr. 28	Pacific Northwest	Eugene, Oregon	Hardboard, pulp chips from waste hog fuel
May 6	Northern California	San Francisco	Log barking
May 7, 8	Northeast	Portland, Maine	Efficient log and lumber processing and utilization
May 20	Pacific Southwest	Los Angeles	Statistical control of furniture manufacture
June 15-17	7th National	Memphis, Tenn.	Diversified programs. Attendance 424.
July 23-24	Midwest	Madison, Wis.	Wood-paper-resin forum
Oct. 5-6	Upper Mississippi	Duluth, Minn.	Portable debarking, wood procurement
Oct. 9	Ohio Valley	Cincinnati, Ohio	Veneer, carbide tools, research
Oct. 13	Pacific Northwest	Bremerton, Wash.	Patents, laminating, adhesives, seasoning, U. S. Navy wood applications
Oct. 21	Pacific Southwest	Los Angeles	Veneer production
Oct. 23-24	Car.-Chesapeake	Richmond, Va.	Panel on gluing, finishing, cores, veneer, logging and utilization
Oct. 29	Eastern Canadian	Montreal, Quebec	Birch plywood grades
Oct. 30-31	Fla.-Ga.-Ala.	Radium Springs, Ga.	Chemical utilization
Nov. 3	Great Lakes	Grand Rapids, Mich.	High frequency heating
Nov. 9, 10	Deep South	Lufkin, Texas	Debarking, chipping, semi-chemical pulping
Nov. 5, 6	Northeast	New Haven, Conn.	Woodworking industry's unsolved problems of common interest to production, management and education
Nov. 12, 13	Midwest	Chicago, Illinois	Wood vs. competition
Feb. 2	Pacific Northwest	Portland, Oregon	Furniture and door manufacture; Hardboard Division meeting.
Feb. 10	Pacific Southwest	Los Angeles	Moisture in forest materials and end products
Mar. 4, 5	Eastern Canadian	Ottawa, Canada	Plywood, grading rules, high temperature drying, laminated construction, containers and pallets, moulded plywood boats, short log bolters

ent phases of forest products. He also discussed the adopted program for substituting abstracts for preprints in 1955, and the replacement of the Annual Proceedings issue of the Journal with a special "Annual Review" number. The latter is to be published closer to the start of the calendar year, and will contain summaries of annual progress by subject matter classification as reported by our subject matter committees. The annual meeting papers will appear throughout successive issues of the Journal thereby getting this information to the membership earlier than otherwise possible. The chairman also described the trends toward publishing more contributed papers and the upgrading of review and publishing standards, the overall objective of which is to establish a Journal which can take its place alongside the finest of other and longer established societies than ours.

5. Report of the Building Committee

W. J. Eason, chairman, outlined the progress which has thus far been made toward erection of a national executive office building in Madison. Real estate in the amount of $9,500 has been purchased and paid for; and preliminary plans for the architecture of the building have been approved. The building will be fire-retardant treated frame construction and will embody many of the newest principles of construction and be representative of a wide range of forest products materials.

6. Report of the Membership Committee

Our membership is growing at an ever increasing rate. It has more than doubled in the last 5 years, from 1200 members in 1948 to 2700 at present.

WOOD PRESERVATIVES

for every purpose

- DECAY!
- STAIN!
- TERMITES!
- MOISTURE!

WOOD TREATING

SALES AGENTS

MONSANTO CHEMICAL CO.
SANTOPHEN 20 (Pentachlorophenol)

WYANDOTTE CHEMICAL CO.
NOXTANE (Sap Stain)

EFURD MACHINE & WELDING CO.
HURRICANE
Peelers. Framers. Trams. etc.

WOOD-TREATING Chemicals Co.
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St. Louis 10, Mo.

LEADERSHIP IN THE PLANER MATCHER FIELD SINCE 1907

This Trade Mark

ON MACHINES IN YOUR PLANT MEANS

HIGHEST PRODUCTION

MAXIMUM QUALITY

LOWEST PRODUCTION COST

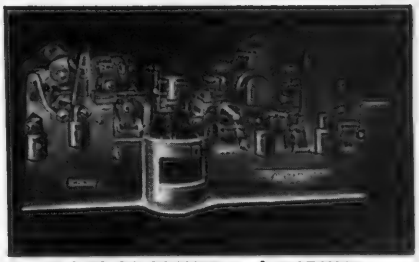
THE most profitable planing mills in operation today are those planned for continuous straight-line production and minimum lumber handling. The heart of such a production line is a quick-change, fast feed modern planer and matcher that produces finely machined lumber—and does it a full 8 hours per shift. There is no place in *today's* planing mill for the machine that ties up production a half hour or more each time a pattern is changed.

New machine developments during the last 20 to 25 years have made the equipment of an earlier era obsolete—*obsolete long before it is worn out.*

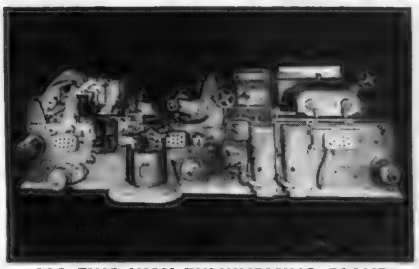
If you are using ancient machines in your planing mill just because they aren't *worn out* yet, we suggest that you honestly compare the equipment you are now using with the available new equipment on the market. Then, determine how much this obsolescence is actually costing you.

We believe you will be agreeably surprised at the many *years-ahead* features found in Stetson-Ross cost-reducing planing mill machines.

You are invited to submit planing, trimming or handling problems for our recommendations without obligation. FREE ON REQUEST: *Your copy of "A B C's of Planing Mill Layout."*

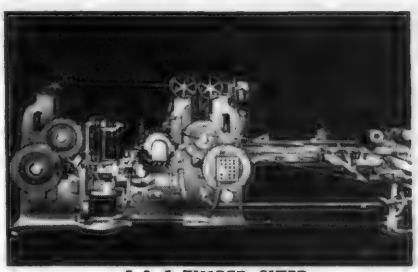


6-10-A1 PLANER and MATCHER
(8 Knife)

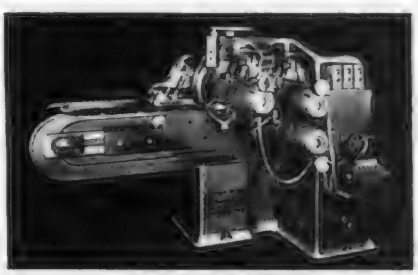


202 TWO-WAY THICKNESSING PLANER and MATCHER
(14 Knife)

6-12-C1 PLANER AND MATCHER
(14 or 16 Knife)



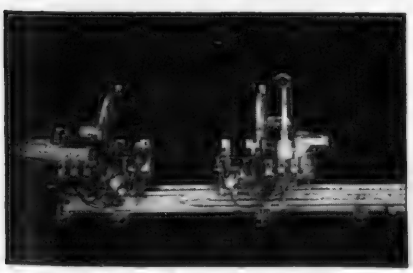
4-A-4 TIMBER SIZER



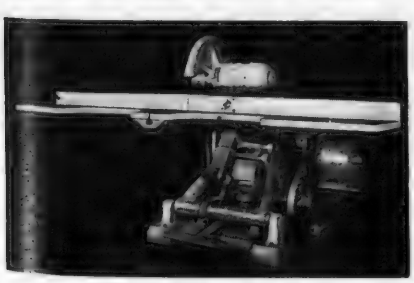
36-A END MATCHER

TRAVELING APRON DECK-CONVEYOR
603-E UNLOADER HOIST

T-33 RANDOM LENGTH TRIMMER
with built-in top and bottom dust removal system



WT-65 AUTOMATIC BUNDLE TRIMMER



T-18 CUT-OFF SAW

STETSON-ROSS MACHINE COMPANY
SEATTLE 4, WASHINGTON

EXPORT DIVISION: 301 CLAY ST., SAN FRANCISCO 11, CALIFORNIA

During the last year membership drive efforts have been very productive. We have obtained 569 new members in fiscal year 1953. This is the result of a strong campaign at the section level in cooperation with the national office.

The total new members joining up is not the whole story because we also lose some members due to change in occupation, resignations, non-payment of dues and death. The net gain in new members over the removals is increasing each year. Although 219 members were lost in f.y. 1953, we added 569 new members for a net gain of 350.

It is significant that as the Society grows and becomes better organized with improved meetings, publications and services, not only do more new members join up, but fewer resign. We can compare the 219 removals in 1953 with removals of approximately 400, 350, 400 and 450 in the four previous years. The number dropping out of the Society in 1953 was about one-half of the previous annual rate.

The net gain was doubled last year; 350 in 1953 compared with approximately 150, 100 and 150 in the three prior year.

Time does not permit naming all the men on section membership committees, But I would like to give credit to all of them and recognize the following section membership chairmen: Bruce Anderson, Florida-Georgia–Alabama Section; Vern Bergquist, Midwest; Paul Graham, Northeast; Pete Garratt, Ohio Valley; Walter Lear, Deep South; Earl McCarthy, Pacific Northwest; Axel Pedersen, Pacific Southwest; Dr. Joseph Risi, Eastern Canadian; Jim Rowney, Northern California; Walt Smith, Carolinas–Chesapeake; Sandy Stuart, Great Lakes.

We should also give credit to the professors and workers in the schools and colleges for their work on membership and to the national office for their help in coordinating the entire program.—FRED ARMBRUSTER, *Chairman.*

7. Report of 9th National Meeting Committee

Chairman, John D. Ritchie, reported on the 1955 Annual Meeting to be held at the Olympic Hotel, Seattle, Washington, June 19–23. Preliminary plans call for two full days of technical sessions; one of subject matter committee meetings; a highlight Lake Washington Puget Sound cruise with dinner aboard; and possible field trips to Simpson and Weyerhaeuser Company operations. A complete ladies program is envisioned, and the event is being tied in with our members' vacation plans.

8. Report of Subject Matter Committees

General Chairman, Moss B. Christian, announced that all 13 committees of the Society had conducted meetings in Grand Rapids and their reports would subsequently be made available to the membership. (For these reports, see pages). During f.y. 1954 two new committees, Marketing, and Veneers and Plywood, have been sanctioned by the executive board. In addition, seven of our 13 committees have been directly responsible for, and are conducting the technical sessions of this meeting. Mr. Christian emphasized that meetings of subject matter committees are open for all members to attend. He introduced the new coordinating chairman for subject committees, Ralph H. Bescher.

Upon motion duly made and seconded all of the foregoing reports were unanimously accepted.

9. Report of Resolutions Committee

1. In recognition that the success of this Eighth Annual Meeting of the Forest Products Research Society is in a large measure due to the foresight, planning, and diligence of the various responsible committees, and in particular of the Grand Rapids meeting committees.

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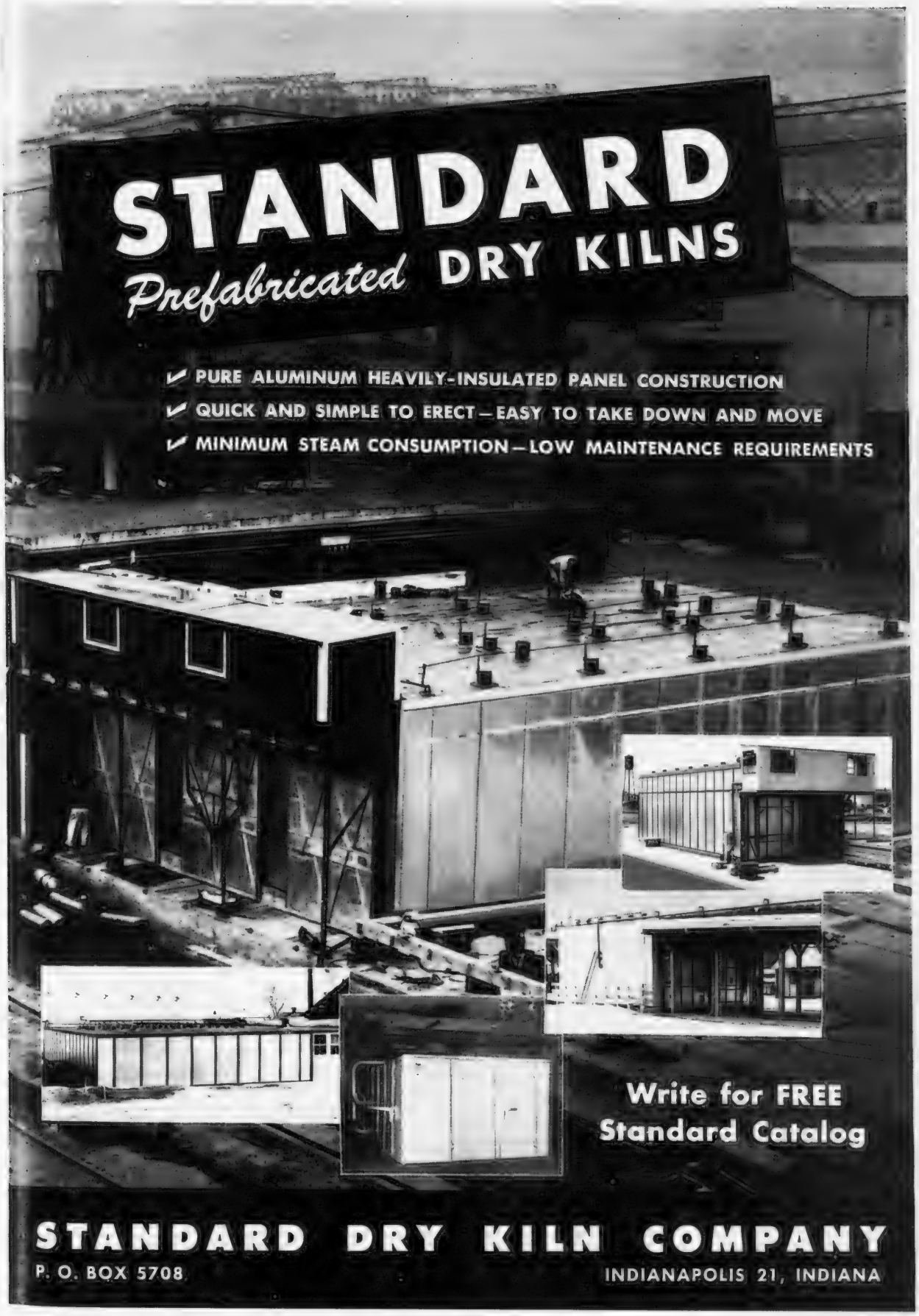
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Be it resolved that the Society hereby acknowledges its appreciation to the Chairmen and the members of those committees for their excellent and successful work.

2. In appreciation of the meritorious services that they have rendered to the Forest Products Research Society during their period of office.

Be it resolved that the gratitude of the Society be extended to all of our out-going officers including executive officers, Regional Board Members and Section Officers.

3. In recognition of the unusual service rendered at the annual meeting by two of our members who had foresight and initiative in organizing the Hiller and Stuart Company and who successfully promoted and conducted a most outstanding Woodworkers Equipment Show,

Be it resolved that the gratitude of the Society and its membership be extended to Robert Hiller of the American Cyanamid Company and Alexander Stuart of the John Widdicomb Company for their splendid coordination and services rendered in conjunction with the annual meeting of the Forest Products Research Society.

4. In view of the splendid cooperation and services provided by our host hotel, The Pantlind, and neighboring hotels in helping to make this annual meeting a success,

Be it resolved, that the appreciation of the Society be extended to the management and to the entire staff and that a copy of this resolution be forwarded to the Hotel.

5. The Society records with deep regret the passing during the past year of the following members:

Don L. Quinn
W. H. Bierbusse
Gustavus J. Esselen
Donald W. MacKinsie
S. Kamesam
C. V. Sweet
Dr. Horace E. Hall
Jacques L. Beinfait
Thure Duvall
Charles William Grindell

Be it resolved that this expression of sympathy to the families and friends of these men be included in the permanent records of this meeting and of the Society. (Those assembled observed a moment of silence)—A. L. Mottet, W. R. Warner, Roy M. Carter, Chairman.

10. Report of the Tellers Committee

Your tellers committee composed of Harold Evans, Forrest Beil, L. N. Erickson, James Hamilton, and the chairman have counted the ballots and report the following elected: President–Elect, Moss B. Christian; Vice President, Ralph H. Bescher; National Nominating Committee: A. B. Anderson; G. G. Marra; H. B. McKean; F. F. Wangaard; Northeast Regional Board Member, F. T. Parrish; Northwest Regional Board Member, J. D. Ritchie. Submitted by K. G. Chesley, Chairman

Upon motion duly made and seconded, the report was accepted.

11. Introduction of New Officers

Retiring President Pauley acknowledged retiring board members Fred Armbruster, W. B. Wilkins, and K. G. Chesley, and introduced incoming board members, R. H. Bescher, F. T. Parrish and J. D. Ritchie, and L. J. Carr. In paying tribute to incoming president Carr's past services to the Society he noted Carr's work in organizing our two California sections, service as national membership chairman, and currently as national technical program chairman.

12. Adjournment

After acknowledging his introduction and referring back once again to his remarks concerning his high esteem for the previous administration headed by R. D. Pauley, President Carr declared the meeting adjourned at 12:00 p.m.

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KENNAMETAL*—the carbide developed for cutting steel shows outstanding results in woodworking operations

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1954 FPRS Subject Matter Committee Reports

ONE OF FPRS most growing activities is its 13 Subject Matter Committees, in any or all of which, any member of the Society may participate. Their responsibilities include:

1. To serve as a point of contact between the field, the Society and its members through meetings, correspondence and publications.
2. Work with Society's annual meeting program chairman in planning and arranging a complete technical session as scheduled by the Executive Board.
3. To hold an annual meeting in conjunction with the Society's national meeting for purpose of reviewing accomplishments and planning future activities.
4. Prepare an annual report on research and developments which have taken place in this field during past year. Also prepare a bibliography of interesting articles published in the field during past year and as far back as the committee desires to pursue.
5. Develop such specific material and engage in such activities within the scope of the field as considered appropriate for the Society.

Attending the annual meeting of Subject Matter committee chairmen were above, first row, left to right: P. A. Patronsky, Wood Machining; Alan Marra, Glues and Gluing; Ralph Bescher, FPRS vice-president and coordinator of subject matter committees; George Marra, Composition Board. Second row: E. J. Locke, Publications; M. B. Christian, FPRS president-elect and past coordinator of subject matter committees; Donald Lubeck, Finishing; Charles Latimer, Quality Control; Frank Parrish, Northeast Regional Board Member; Roy Carter, past president; and Reavis Sproull, Chemical Utilization. Third row: H. O. Fleischer, Veneers and Plywood; L. J. Carr, FPRS president; Phil Creden, Marketing; Fred Simmons, Logging and Milling; M. J. Peters, Detroit Lumbermen's Ass'n.; and Leif Espanas, Wood Drying. Not shown are Bill Darwin, Wood Preservation; Ken Kruger, Packaging; and Jim Bethel, Veneers and Plywood.

EDUCATION — May 4 — Acting Chairman, A. J. Panshin, Michigan State College

44 persons attended the meeting which was opened by the chairman calling upon Mr. R. C. Deckert for his committee report on the feasibility of standardization of titles for graduates of the forest products and wood technology curricula. The discussion that followed confirmed the committee's conclusions that any proposals for a standardization of names for the graduates of the forest products and wood technology curricula are premature.

Dr. Robert W, Hess suggested that the education committee could attempt to develop programs for (a) training for technical positions, (b) training for production work and (c) training for office work (personnel and industrial engineering).

Professor Ben S. Bryant said that the problem is mostly that of getting someone to train. Representatives of other schools agreed that one of the most pressing problems is how to attract qualified students to the forest products course.

Dr. F. F. Wangaard suggested that the need for dissemination of information is in two directions: (a) Information to the employers on the need for technically trained personnel, and (b) Information to prospective students on the opportunities for a career in forest products.

Dr. J. A. Hall thought that this problem is too complex to be solved in a short meeting, and proposed that we call a special meeting of educators and industry representatives to discuss thoroughly this entire question of training technical personnel. For this purpose he offered the facilities of the Forest Products Laboratory.

Dr. F. E. Dickinson moved that the Chair appoint a committee to work out the details for such a coordinated meeting, to be held within a year. The motion was seconded and passed. Every effort will be made to call such a meeting in the fall of 1954.

Moss Christian pointed out that the education committee is entitled to a technical session at the next national meeting, to be held in Seattle. C. D. Dosker moved that the committee sponsor a technical session. Motion seconded and passed.

Dr. Frank H. Kaufert inquired why it is that industrial trade organizations put out a great deal of educational literature to high schools and grade schools on such subjects as the "keep green" programs, but not on the subject of opportunities for careers in forest management and forest products technology? No one present could provide a satisfactory answer to the query, but C. D. Dosker thought it might be desirable to address a letter to the NLMA asking for assistance in calling attention to the opportunities for careers in the forest products industries.

GLUES AND GLUING—May 5—Chairman, Alan A. Marra, University of Michigan

The meeting was called to order at 9 A.M. by the Chairman, A. A. Marra, with 48 in attendance. He summarized the purpose and aims of the committee and spoke briefly on the development of a technical session on glues and gluing for the Seattle meeting. The meeting was then opened for general discussion.

Tom Cook, National Casein Company, Chicago, reported on some new developments in adhesives. R. M. Williams, American Marietta, Seattle, Washington reported on recent West Coast developments. Current research is being beamed toward modification of existing materials rather than the development of new ones, all with the view to cutting glue line costs.

Chairman Marra asked Mr. Van Epps, Stromberg–Carlson Co., Rochester, N. Y., to speak on gluing techniques by industry. There being no comments on Mr. Van Epps report, Chairman Marra asked Mr. R. Blomquist, U.S. Forest Products Laboratoty, to lead a discussion on methods of test for glues and glued joints. Chairman Marra asked Mr. Cook to summarize developments in new glued-up materials. Mr. Cook listed the applications. Mr. Williams reported on new gluing equipment on the market.

At this point the chairman asked Mr. Yavorsky, N.Y.S. College of Forestry, to report on his work with stress coat lacquers. Following Mr. Yavorsky's paper, Mr. Worth, Bureau of Ships showed movies on glued laminated timbers.

Glues and gluing.

Quality control.

Mr. Miles moved and Mr. Williams seconded that the Committee have another session in Seattle, carried. The chairman appointed Don Redfern and B. S. Bryant as coordinators for that meeting.

PACKAGING—May 5—Chairman, Earl R. Stivers, Package Research Laboratory

A program was planned for the 1954 meeting to fit the Michigan area, namely, Furniture Packaging and Automotive Parts. Six outstanding papers were presented at Grand Rapids and kept an audience interested for the entire session.

At the meeting the committee voted to request a Technical Session on Packaging at the 1955 Annual Meeting. It was agreed that the best interests of the Society will be met if a proper balance is maintained between research, technical and production papers in the program. A suggestion was made that a panel discussion be included and Eastern representatives be encouraged to participate.

Mr. K. W. Krueger of the Forest Products Laboratory was recommended to the President for appointment as Chairman for the ensuing year.

WOOD MACHINING—May 5—Chairman, L. A. Patronsky, Wabash Screen Door Co.

Chairman Patronsky in his introductory comments gave a brief background of the committee organization and its general purpose. He also gave a brief "behind-the-scene" view of the papers to be presented at this annual meeting of F.P.R.S. on wood machining. Chairman Patronsky also stated the objectives of this committee and indicated the types of projects this committee could instigate, sponsor or carry on among its volunteer members.

A preliminary report on the topic of nomenclature was made by the Subcommittee on knife nomenclature headed by Stanley Studstrup, of Wisconsin Knife Works. Drawings with suggested names for the various angles, parts, sizing and other pertinent information which will be submitted to the machine knife industry for acceptance, correction or rejection were passed among the group.

A Continuous Feed Veneer Jointer

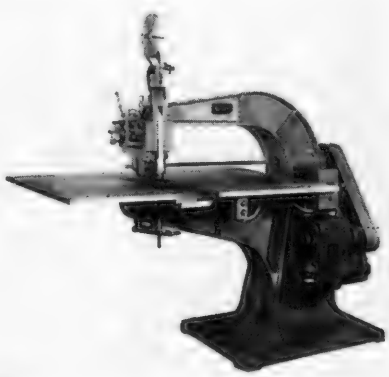
built especially for use on long and buckly veneers, and thoroughly proven in operation.

Equipped with a Glue Spreading attachment that has been pronounced the Best on the market today.

Dennis Veneer Taping Machine—

The Standard Taping Machine in the Woodworking Industry. Thousands in operation all over the world.

Improved and built better than ever.



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COE YEARS OF CONCENTRATION

on design and manufacture of CONTINUOUS DRYERS

FOR VARIOUS WOOD PRODUCTS, VENEERS & FIBRE BOARDS

8 Line Gas Fired Coe Fibreboard Dryer

Wet end 10 section, 4 line, 12 ft. roll Model 48 Coe Veneer Dryer.

.Coe Dryers, in their present form, are the result of more than 50 years of specialization. The original Coe Dryer was built and sold in 1902.

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Our engineering and research departments are always willing and anxious to cooperate in the development of drying processes for new wood products.

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Wood machining.

Packaging.

Mr. Norman C. Bye of Henry C. Disston & Sons, Inc. made the report on the work of this Sub-Committee. Some significant progress has been made in clarifying terminology. Mr. Bye signified that his committee expected to have a more complete report at the next meeting.

Mr. J. C. Hampton, Sales Manager of Redco Tool Division reported on a unique method of surfacing acoustical tile with a series of overlapping grooving saws instead of knives.

The subject of machine noise in wood working machines and buildings was introduced. This brought forth a variety of comments regarding how it might be handled. The general opinion was that it was of sufficient importance to justify an attempt to gather more information. Mr. Chandler Jones, who introduced the subject, was to report to Chairman Patronsky on any further development.

Chairman Patronsky requested that suggested names be placed before the group for selection of Chairman for 1954–56. Mr. Norman C. Bye suggested that Chairman Patronsky continue as chairman. This was seconded by Rust F. Gray of Diehl Machine Works. It was unanimously passed that Mr. Patronsky continue for another term.

A discussion among those present was that the papers for the Seattle meeting should be predominately pointed to West Coast operations and activities, although some of general nature should be included. Mr. Jeff Davis of the U. S. Forest Products Laboratory suggested that "West Coast Hardwoods" and "West Coast Softwoods" would be two good topics. Others suggested were—"Cutting Veneers at High Speeds"—"Chipper Knives"—"Noise Abatement in Machines and Surrounding Equipment"—"Machining of Particle and Hard Boards"—and "Methods of Determining of the Sharpness of Cutting Edges".

A sub-committee to prepare a report on Wood Machining will be selected. Everyone on the general committee, plus any other interested persons, will be given the opportunity to aid in compilation of this report.

Mr. Crowder of Johnston–Crowder Mfg. Co. suggested that a wood machining information booklet be compiled for general use in the industry. Chairman Patronsky suggested that this committee carry the ball and coordinate the efforts of individuals, committees, trade associations and colleges and universities. It is believed that such a report or booklet would do much to standardize wood machining techniques. niques.

There was considerable discussion on Carbide Tool maintenance. Chairman Patronsky commented on the work done

For Continuous, Fast, Flush Door Sizing Production . . .

Investigate the "Challoner" Tandem Unit with its Automatic Transfer Unit.

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National Furniture Mfg. Co., Evansville, Ind., operates this Moore Unit-Package Cross-Circulation Kiln for seasoning hardwood dimension.

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Wood preservation.

Wood drying.

along this line by University of Michigan and New York School of Forestry at Syracuse, N. Y.

Chairman Patronsky also suggested that this committee prepare a list of material available with names of persons who could be available to help with programs at regional meetings on the application, use and maintenance of Carbide Tools.

WOOD COMPOSITION BOARD —May 5—Chairman, George G. Marra, Washington State College

Meeting opened with discussion on Committee membership. New members are needed to furnish coverage of: equipment, consumers and fabricators, sales, and molded products.

General discussion of latest developments followed on: processes, resins, research and testing, properties and uses, equipment and economics.

It was agreed to have a Technical Session on Composition Board at the 1955 National meeting in Seattle.

WOOD PRESERVATION—May 5 —Chairman, W. N. Darwin, TVA

Meeting called to order by Gardner Garlick acting for Chairman W. N. Darwin, who was not present. In the absence of Secretary Mark M. Lehrbas, Ira Hatfield was appointed temporary Secretary.

Mr. Garlick opened the meeting of 28 persons by reading the functions of the Wood Preservation Committee as drawn up last year. They were: 1. To keep before the FPRS developments in the field of wood preservation of interest to the Society. a. Research in developing, b. Materials used, c. Specifications for treating wood products. 2. Assistance to members in making contacts relating to sources of technical information on wood preservation. 3 Serve as liaison for the Society with the American Wood-Preservers' Association and others. 4. Call attention to developments in wood preservation to the Society. 5. Coordinate with committee from other agencies such as the BPIS&AE, Bureau of Entomology & Plant Quarantine, etc. 6. Advise and assist in developing programs in the field of wood preservation for the National and Section Meeting of the FPRS.

Dr. R. H. Colley, Technical Director, Bernuth Lembcke Co., Inc., New York, New York presented a paper on the subject "Problems In Preservative

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COPPER NAPHTHENATE LIQUID 8%

Description	Clear green liquid	Viscosity	13.0 poises
Copper content	8%	Specific Gravity	1.02
Solid copper naphthenate content	72%	Pounds per gallon . . .	8.5
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Conforms to National Bureau of Standards' Commercial Standard CS 152-48 (Sept. 25, 1948) "Copper Naphthenate Wood Preservative" concentrated type.

If you need Copper Naphthenate Liquid of any special concentration, Harshaw can quickly manufacture it for you. For prompt service send your order to the nearest Harshaw branch sales office.

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Permanent Displays New York, Chicago, San Francisco, Los Angeles, High Point

January 12, 1954

Mereen-Johnson Machine Company
Minneapolis, Minnesota

Attention: Mr. R. E. Johnson

Gentlemen:

At the request of Mr. Claude S. Sutton we are writing to give you a brief report on the performance of the two #400 M-J Tenoners we have had in operation for the last eighteen months.

In our opinion these machines have given exceptionally good performance from a quality and production standpoint. With the multiple "V" type Mereen-Johnson corrugated feed chains and quick chain snap-on dogs, accuracy of cutting and quick setups are accomplished. The two machines are both sturdy and the heads, motors, etc. well balanced, which permit us to run at maximum speeds and obtain uniformly accurate dimensions at the lowest possible unit cost.

Our operators, foremen and plant superintendent are highly satisfied with the two #400 Tenoners and believe them to be very versatile production machines.

Very truly yours,

J. W. Brandon

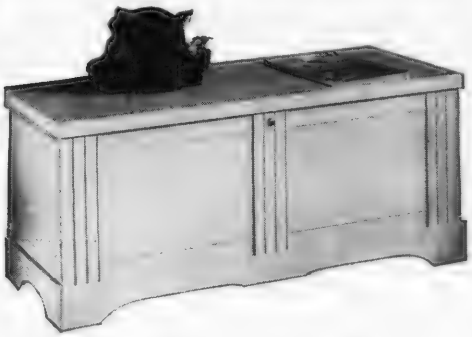
J. W. Brandon
Plant Manager

JWB:vlf

"Maximum Speeds...
Uniformly Accurate Dimensions...
Lowest Possible Cost"

with our

MEREEN-JOHNSON
NO. 400 TENONERS



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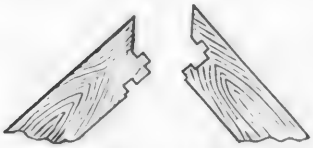
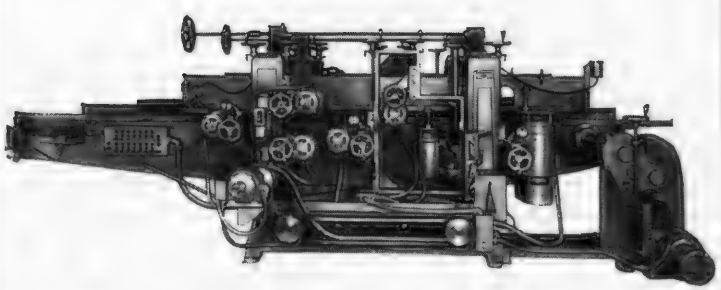


Special Lane lock joint made with the No. 400.



★ Rugged welded steel construction
★ Precision multiple V chain
★ Hi-Speed copes

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4401 LYNDALE AVE. NO. • MINNEAPOLIS 12, MINNESOTA

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TENONERS | VENEER & PLYWOOD SIZERS & JOINTERS | RESAWS

Wood particle board.

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Evaluation." He pointed out that our major problem is to coordinate our efforts with those of the American Wood–Preservers' Association. He further stated that we need to know more about the biology of the various organisms that cause wood deterioration and their relation to the habitat of the material being used.

A paper entitled "Performance of Laminated Preservative-Treated Railroad Bridge Stringers" by M. L. Selbo, Chemical Engineer, U. S. Forest Products Laboratory, Madison, Wisconsin and H. W. Angell, Technical Director, American Lumber & Treating Co., Chicago, Illinois was presented by title.

Next there was a very stimulating presentation by Mr. B. C. Williams, Master Woodworker, Norfolk Naval Shipyard, Portsmouth, Virginia. The title of his paper was "Pre-Serving For Products, Skills and Dollars." Mr. Williams asked, "What is the Norfolk Naval Shipyard doing along wood preservation lines?" and he answered by telling of the many ways the Shipyard uses wood preservatives.

The next paper was by C. S. Walters, Associate Professor in Forest Utilization Research, University of Illinois, Urbana, Illinois. It was entitled "The Effect of Solvent Aromaticity and Boiling Range on Blooming of Pentachlorophenol and the Decay Resistance of Ponderosa Pine." By the use of slides, Dr. Walters illustrated how the aromatic content of petroleum oils influence the blooming (crystallization of chemical on the surface of the wood) and decay resistance of treated wood.

Dr. Walters' paper was followed by a paper by L. I. Winebrenner, Laboratory Director, Protection Products Manufacturing Co., Kalamazoo, Michigan on the subject "The place of Water Repellents in the Preservative Field." Using slides of the illustrations given in the paper, Mr. Winebrenner showed the remarkable and practical way in which water repellent preservative solutions reduce seasoning checks and warping of treated wood exposed to the elements.

The last paper presented was by Henry W. Hicock, Forester, The Connecticut Agricultural Experiment Station, New Haven, Connecticut. It was entitled "Wood Preservation by Simple Methods." Mr. Hicock pointed out that the work at the Connecticut Station involved only native woods of Southern New England and results were reported only for conditions prevailing in that locality. The conclusions drawn were that where reasonable pains are taken to treat wood by the more simple methods, the "standard" preservatives

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PARKWOOD HI-DEN

HI-DEN is made from selected woods, impregnated, laminated and compressed. It is tough, dense, moisture resistant, dimensionally stable and has a low co-efficient of friction. Widely used in forming tools, jigs, textile machinery parts, knife handles.

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GENUWOOD is a beautiful decorative laminate made from a variety of genuine wood veneers. It has a 100% melamine finish. Scratch and acid resistant. Cigarette proof. Retains all the natural lustre of the original veneers.

PARKWOOD DECORATIVE

A beautiful laminated plastic with a wide range of colors, exclusive patterns and high quality imitation woods. Manufactured in 1/16" thickness for tops and in 5/32" hardboard (Parkwall) for walls, wainscoting, etc.

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Singleness of Purpose...
A BRIEF MESSAGE ABOUT CHAPMAN CHEMICAL COMPANY
The business of Chapman Chemical Company is based on one idea: to make wood last longer and thus be of greater value and utility to industry, farmers and homeowners.
Extensive Chapman research and technical service have been responsible to a great extent for the acceptance of clean PENTA-treated forest products.
Just as important has been the recognition of PENTA'S effectiveness by treating plants, railroads, utilities and other users. Their cooperation has been of vast service to all users of forest products . . . and has helped Chapman Chemical Company realize its one great objective, that of making wood last longer.
CHAPMAN
CHAPMAN CHEMICAL COMPANY
Distributors of PENTAchlorophenol for The Dow Chemical Co.
Dermon Building, Memphis 3, Tenn.
Terminal Sales Building, Portland 5, Ore.

Marketing.

Wood finishing.

can be expected to give a very measurable extension to the service life of posts and other items so treated.

In the short discussion that followed the presentation of these papers Mr. George Olson said he felt that the FPRS should help assemble and disseminate information that would help get wood into more end uses and that would help hold and also help regain wood markets.

Mr. Ralph Bescher stated that a good paper showing the relative merits of wood for various uses and pointing out how wood can be used to better advantage would be very timely. Another paper might show how wood could move into the competitive picture better—not necessarily cheaper. His feeling was that there is a real need to educate the retailer and user on the merits and proper use of wood.

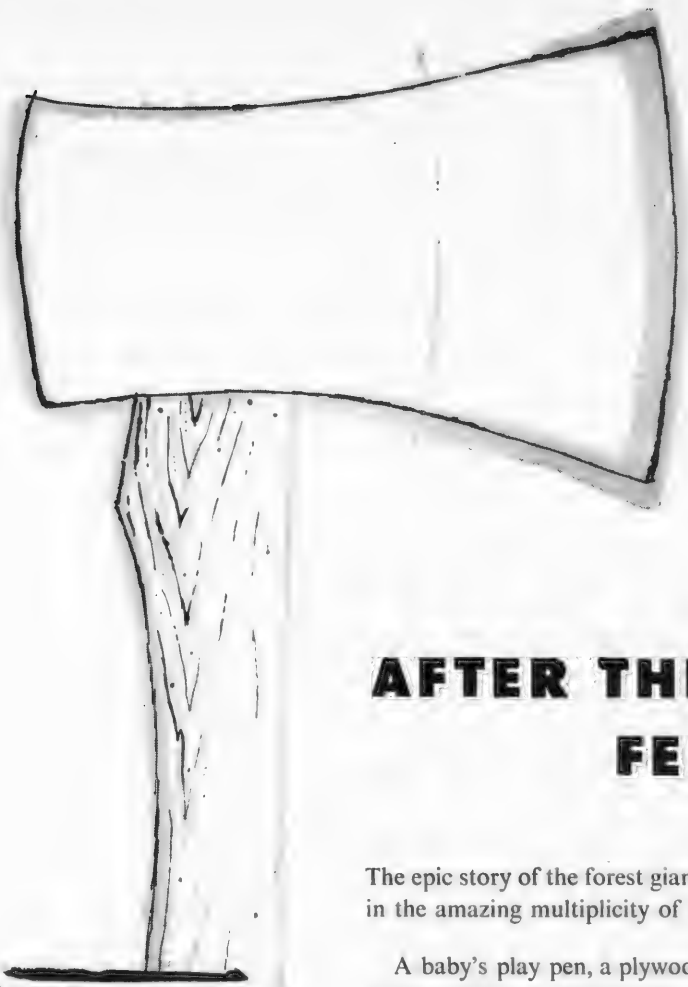
Mr. Phil Creden stated that if such papers were prepared, Edward Hines Lbr., Co., Chicago, would be glad to give them wide spread distribution.

WOOD FINISHING — May 5— Chairman, B. E. Clatworthy, R. C. A.

The first subject taken up was a letter from Mr. G. G. Sward, presented by Mr. Fuller, stating that the Institute of Paint and Varnish Research was not preparing a glossary of paint terms. Evidently, some people were under this impression and Mr. Sward wanted to correct this assumption.

Mr. Krupp asked the question, "Would the wood industry be interested in the quick drying of coating materials by using sources of heat such as infrared?" The subject was discussed and those present felt that the industry would be interested in learning more about quick drying. Although only limited work has been done in the United States, England has been using infrared for several years with apparent success. It was agreed that this would be a good subject for a future paper. Mr. Bruneau raised the question, "What are the long term effects on cabinetwork that have received accelerated drying schedules?" No conclusive answer was given to this question.

The balance of the time was devoted to discussing who the principal beneficiaries from papers presented on Wood Finishing are, and what they would like to have papers cover. The men who attended this meeting felt that there should be a Wood Finishing Section in 1955.



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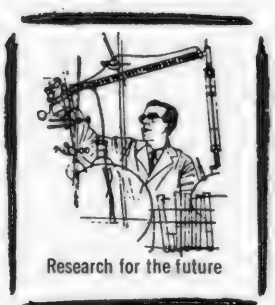

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WOOD DRYING—May 5—Chairman, Raymond C. Rietz, U. S. Forest Products Laboratory

Chairman Rietz opened the meeting with 29 attending at 2:15 p.m. with a brief report on the status of the Wood Drying Committee Report *"Status of Seasoning in the U. S. and Canada"* which will be completed and submitted for publication within the next two months.

The topic of the Committee's NEWS-DIGEST articles was then brought up for discussion. Rietz pointed out that the first issue was made in April 1953 and that issues are made once a month. The NEWS-DIGESTS were prepared by himself and the other Committee members. Approximately 1600 copies of each NEWS-DIGEST are mailed to the kiln clubs for distribution to their membership. He had recently received a request for copies from the Library of the Department of Agriculture. So far, the Society has printed the NEWS-DIGESTS and the Wood Drying Committee is the only Committee preparing articles of this kind.

Copies are available to individuals upon request if the requests are directed to Rietz at the Forest Products Laboratory, Madison, Wisconsin. The College of Forestry, State University of New York, has a mailing list of those interested in seasoning and copies of the NEWS-DIGEST are sent to them to be mailed. The question was asked if this could be done by other organizations and Rietz said that he could send a limited number of copies to other organizations with suitable mailing lists.

The question was asked if the Committee stimulated the formation of kiln clubs. Rietz replied that the Committee had not and was not expected to do so but that it was a function of the Committee to work with the kiln clubs and to act as a liaison between the clubs and the Society.

The status of the Committee's project on the list of seasoning research activities by research agencies and other groups was brought up for discussion. The question was asked whether or not those receiving the list could not be polled prior to the annual meeting for the current status and the answer was made that this could probably be done and it could be included as a part of the Committee's annual report.

The fourth subject of discussion brought before the Committee was the Seasoning Lecture. Chairman Rietz explained that the primary purpose of this Lecture would be to recognize the contributions of outstanding individuals to the development of seasoning practices. He expressed the hope that some person could be selected and underwritten by the Forest Products Research Society or some organization to prepare and present such a lecture honoring some individual at the annual meeting of the Forest Products Research Society, at kiln clubs, etc. H. D. Tiemann, W. Karl Loughborough, and Joe Steele were mentioned as men who might be honored.

The question was raised as to whether or not the Forest Products Research Society was strong enough financially to underwrite the Seasoning Lecture and it was pointed out that it may be necessary to have companies underwrite them. The recommendation was made that living men be recognized by the Lecture as soon as possible.

Discussion later in the meeting brought out the possibility of trade magazines being receptive to the idea of sponsoring the Lecture. The recommendation was made that a subcommittee be appointed to investigate all possibilities of sponsorship.

The next subject for consideration concerned the distribution of reprints of articles in full in lieu of digests of the articles. The recommendation was made that a subcommittee be appointed, or Committee members take it upon themselves, to sound out the kiln clubs in the possibility of their

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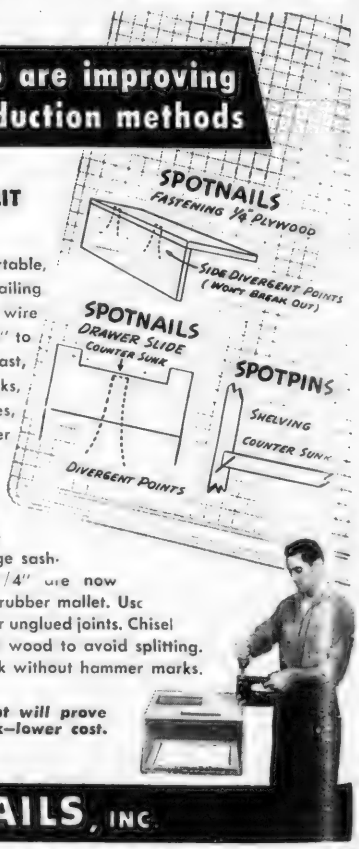

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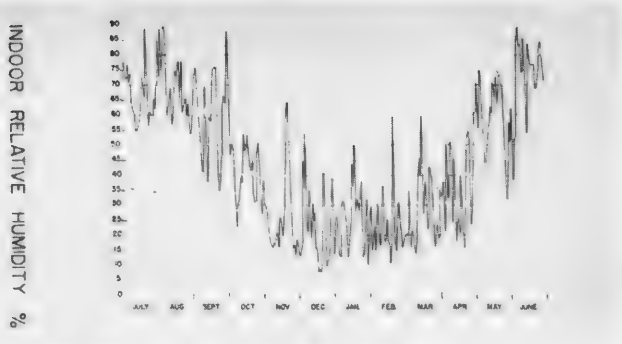

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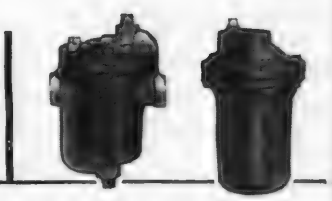

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financing the printing and distribution of reprinted articles.

Chairman Rietz urged all Committee members to encourage articles for publication of the Journal of the Forest Products Research Society.

The Committee was asked to discuss the possibility of having a technical session at the 1955 meeting in Seattle. A poll of the members showed all members present to be in favor of the session. The following subjects were suggested for the session:

(1) Report on the MacDonald process (E. D. Marshall)
(2) Sticker stain in hardwoods
(3) Vapor drying (by Cantrell)
(4) Dry kiln clubs—objectives and accomplishments (by a member of management)
(5) Air drying ponderosa pine in the Southwest (by Ed Peck)
(6) Kiln drying of second-growth Douglas-fir
(7) Warping of Douglas-fir studs
(8) Kiln drying of Northwestern hardwoods
(9) Kiln-Mo-Trol (by Delmhorst)
(10) Sticker costs
(11) Energy requirements in drying

The suggestion was made that about 60 percent of the program be devoted to West Coast woods.

Chairman Rietz read the paper "The Outlook for High-Temperature Seasoning in Canada" by J. L. Ladell, and a discussion was led by a panel consisting of A. C. Knauss and J. S. Mathewson. Mr. Knauss gave a brief but detailed description of the European high-temperature kilns and their operation.

Several questions were asked about the effects of high temperatures on casehardening. Discussion followed concerning the plasticizing effect of high temperatures.

QUALITY CONTROL—May 5—Chairman, Charles Latimer, Nickey Bros.

The annual meeting of the Subject Matter Committee of the Forest Products Research Society was called to order by its chairman, Mr. Charles Latimer at 2:10 p.m.

Minutes of the 1953 meeting in Memphis, Tenn. were read and approved. Mr. Bethel commented on the paper he had prepared as a report of the Committee and it was agreed to submit same as a preliminary report for publication in the annual reports of Subject Matter Committees.

The question of the proposed brochure on principles of statistical quality control was discussed and it was agreed that work should proceed on this project. Messrs. Latimer and Bethel agreed to work on this brochure during the N. Carolina State College Quality Control Short Course at Myrtle Beach, N. C., in August, 1954.

In view of the difficulty in securing suitable papers, it was agreed that no Technical Session would be requested for the 1955 Meeting at Seattle but that such a request would be made for the 1956 Meeting at Asheville, N. Carolina.

Mr. Latimer asked that the Committee members be alert for sources of future quality control papers.

Mr. Latimer stated that he would circulate a list of persons in the woodworking field who are interested and/or active in quality control and asked that members add such names as they may know.

Mr. Wylie stated that, in the absence of the Technical Session, he felt the Committee might work through the various F.P.R.S. Sections in promoting quality control.

It was agreed that the Committee would limit its activities to the wood using industries and would not promote or publicize quality control methods in other industries. It was further agreed that the scope of the Committee's work should be such as to avoid overlapping other Subject Matter Committees as much as possible, partic-

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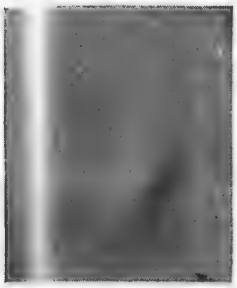

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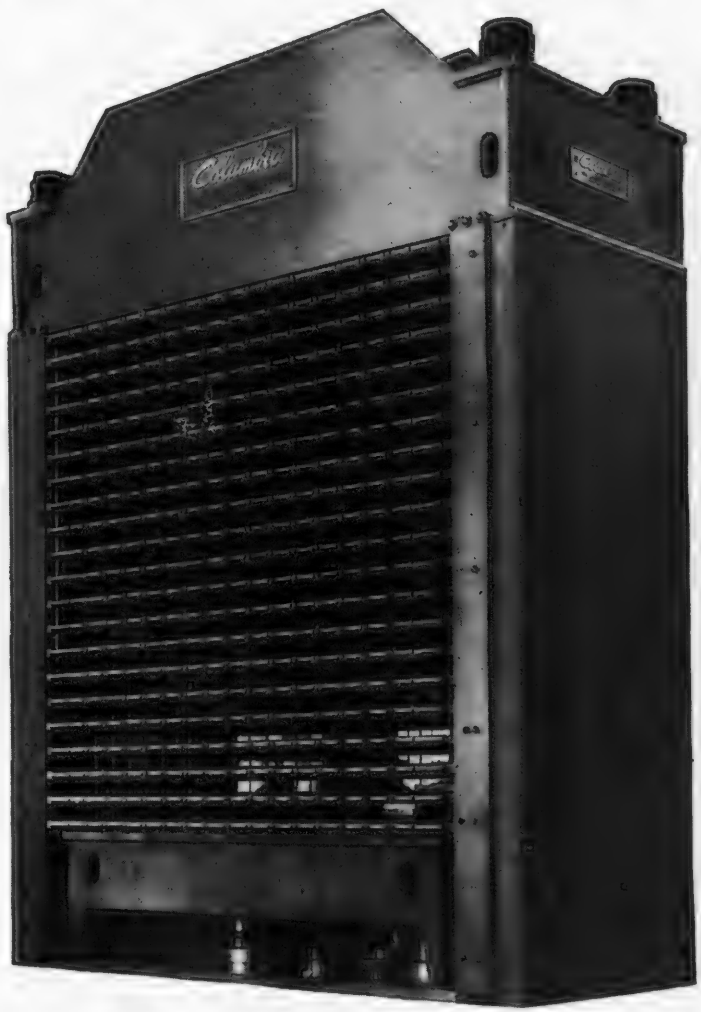

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ularly in the areas of equipment, tests and testing methods, etc.

It was agreed to devote the 1955 Committee meeting to an educational session open to the convention members. This function will be organized and handled by Mr. Ripley.

Mr. Wylie was appointed to investigate the possibility of having an exhibit booth at the 1955 Seattle Meeting along quality control educational lines. Such a booth may be sponsored either by New York State College, North Carolina State College or, perhaps, a local section of the American Society for Quality Control.

"Be it resolved: The display sponsored by the North Carolina State College School of Forestry on quality control at the Industry Show held in conjunction with the 1954 annual meeting of F.P.R.S. is held in high esteem by the Quality Control Committee of the Society.

CHEMICAL UTILIZATION—May 5—Chairman, R. C. Sproull, Herty Foundation Laboratory

The Meeting was called to order at 2:30 P.M. by Chairman, R. C. Sproull.

The Chairman appointed H. B. McKean Secretary of the meeting.

R. C. Sproll stated that the General Chairman of Subject Matter Committees had asked the Committee to prepare an abstract and bibliography in the field of Chemical Utilization. Sproull suggested that the best way of handling this work would be to break down the general field of Chemical Utilization into specialized fields and then assign a committee member to each field for the preparation of the bibliography and abstract. It was decided to develop the classification on the basis of processes. The processes and the person suggested to compile the abstract and the bibliography follow:

Extractives: Dr. Pomeroy or Dr. E. F. Kurch

Hydrolysis: Dr. E. E. Harris

Delignification: Dr. Gardner Chidister or R. J. Seidl

Pyrolysis: K. G. Chesley or Art Goss

Fractionation: A. K. Esterer

Microbiological: A. H. Jenkins or other Canadian to be assigned

The group attending the meeting agreed that the 1955 National Meeting of the Forest Products Research Society should include one or more sessions on Chemical Utilization. The Committee agreed to suggest a session on Hydrolysis and a session on Park Utilization to the 1955 Program Committee. Under Hydrolysis the following subjects were suggested: Economics in which the price of imported molasses and the utilization of lignin should receive considerable attention. Hydrolysis of material other than wood, a subject which could be presented by a member of the U.S.P.A. Lab at Peoria, Illinois, or by a chemist from the Archer Daniels Midland Corporation. Under Bark Utilization preliminary suggestion included a discussion of bark properties of various species and the review of activity in the field of agriculture used for bark such as stock litter and mulches.

LOGGING AND MILLING—May 5—Chairman, Fred C. Simmons, North East Forest Experiment Station

Chairman Fred C. Simmons opened the meeting of 6 Committeemen and 21 guests at 2:00 p.m. and briefly discussed committee accomplishments. Each member of the committee acted as its representative in his own section of the country, advising sectional officers of F.P.R.S. on developments in the subject matter field, and cooperating with other organizations interested in logging and milling. An outstanding example of the latter was the organization and presentation of sawmilling clinics at two recent logging congresses

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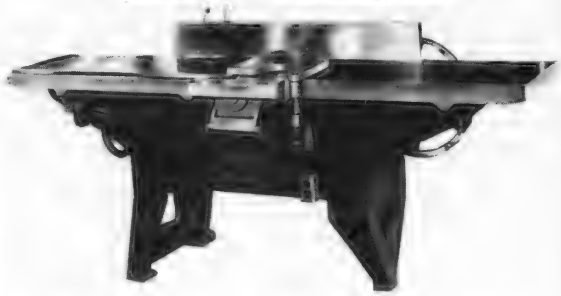

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in the West, the Redwood and the Willamette Valley. Milton Mater, chairman of the sawmilling subcommittee, was the leader in this effort.

The second item of business was the presentation of the report "Outstanding Developments in Logging" by Mr. Leland Hooker.

Discussion followed Mr. Hooker's report. Mr. E. E. Matson described developments in the Wyssen Cableway System of logging, and its adaptation to western conditions. Mr. Wyssen has built a unit which will be heavy enough to handle 10 ton logs, have a span of 1¼ miles and reach 250 feet to each side. A question was raised regarding the "Skyhook" and its current status. It was reported that because of impracticability from a safety standpoint and for other reasons the skyhook is not in operation for logging purposes either in the west or south, where it was first employed. The subject of the status of the chemical debarking of pulpwood was raised. It was reported that during 1953 approximately 150,000 cords had been treated for harvesting in 1954. This technique is still the object of research. It has been successful with hardwoods, but insect damage and stain have mitigated its usefullness for softwoods. Portable chippers were discussed on the basis of types, the breakdown chipper and the controlled chip size chipper. Investigation is under way in the south to determine feasibility of chipping material below four inches in diameter. This immediately raises the question of harvesting costs for material of this size, which question has been a limiting factor in the northeast, where several investigations of utilization of small thinnings have been conducted. There is a good possibility that the air flotation method of separating bark and wood in chips will be developed further to produce a chip cleanliness suitable for all pulping purposes.

Third item was the presentation of Mr. Milton Mater's paper, "A Report on Developments in Milling During 1953. In Mr. Mater's absence the paper was read by Mr. Henry F. Horton. A question was raised regarding the success of the "Duo-Kerf" saw teeth when applied to bandsaws and sash gang saws. E. E. Matson reported that this saw has been tested on a band mill by Weyerhaeuser Timber Company and that at slow feeds it worked well. The same is true of the sash gang saw, but at higher feed speeds in both cases the saws tended to snake. The fine sawdust produced in the side cutters apparently slipped out of the gullets and caused heating difficulties. The following were mentioned briefly as new developments which either have not come to the attention of the average lumberman or have been only recently promoted: The "scrag" saw operation for manufacturing dimension from small softwoods; the Mater Mobile Mill; new metal detectors, such as the one made by RCA; the Dewey Williams saw-line barker; the increasing interest in bolter saws, and the use of chipbreaker types of teeth or shanks in inserted point circular saws.

Fred Simmons reported to the committee and its guests on the subject "Standardization of Small Sawmill Performance". He sketched the origin and development of the movement to promote better standards for lumber products and the participation of ASA, ASME, and FPRS. The Wood Working Section of the ASME is formulating accuracy standards which are confined largely to thicknesses. Individuals are being requested to cooperate by measuring boards, dimension stock, and timbers at 100 mills and to send their results to Dr. Bethel at the N. C. Wood Products Laboratory for analysis. The purpose is to determine reasonable standards of accuracy for the small mill.

In conjunction with the above project the FPRS milling subcommittee will prepare a pocket handbook to be published by ASA, which can be used to assist the small sawmill operator in meeting the standards. In the hands of a lumber concentrator this handbook

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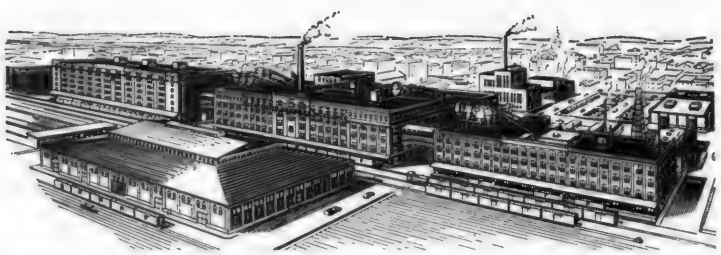

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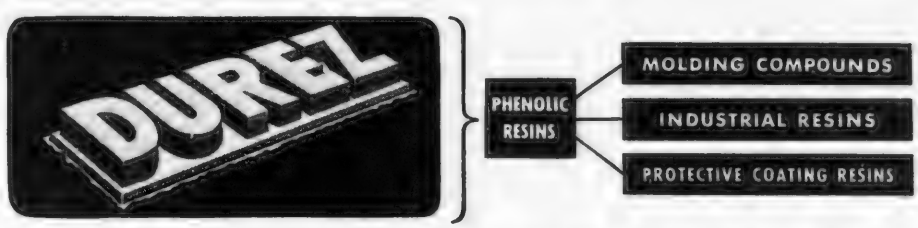

PHENOLIC RESINS THAT FIT THE JOB

could be provided his suppliers to show them specifically how they may meet the standards. It will contain minimum mill machinery specifications which are recommended for production of uniformly accurate lumber products; but the committee, for the time, rejected recommendations for inter changeability of parts between makes. It will also contain instructions for mill setup, operation and maintenance. It was suggested that this handbook should also include tabular information such as comparison of log rules, decimal equivalents of gauge sizes, a glossary, etc. One further suggestion was made from the floor to the effect that it should include information of an engineering nature, such as power requirements, pulley and belt sizes, edgers, sorting chains, blowers, etc. This is to be taken under consideration.

The principal matter for consideration by the logging subcommittee is the setting up of specifications for wood chip standards. Both producers and users need this information which ties in closely with the use of primary mill residues for pulping purposes. The question was raised by Mr. Hooker that since the mill requirements set the standards, how can this situation be changed. One solution is to establish a committee to study the problem from both the user's and producer's viewpoints and to arrive at workable modifications of present specifications. A committee in eastern Canada has been working on this and their preliminary findings will be made available to us, with assurance of future close cooperation. In connection with the purchase of pulpwood it was noted that the payment for pulpwood by weight was increasing. The results are sounder wood and more closely trimmed knots.

The following resolution was introduced by Mr. Leland Hooker at this point:

> The Logging and Milling Committee of the Forest Products Research Society, recognizing the need for impartial agencies to evaluate logging methods and equipment and record and report data thereon, with results of such studies to be made available to the industry, resolves to lend its support to such activity.
>
> *Be it further resolved that:*
>
> A. The Logging committee effect itself as a clearing house for such technical information as may be developed.
>
> B. The Logging committee should contact the presently known impartial agencies, commending them for their interest and soliciting their cooperation in establishing this FPRS clearing house.
>
> Be it resolved that the Forest Products Research Society endorse the efforts of organizations promoting safety programs within the logging industry, and to offer them our whole-hearted and enthusiastic support through individual member participation in safety programs.

After considering the resolution, the committee agreed to take the matters under advisement and to investigate channels for implementing its suggestions.

The question was raised regarding the Logging and Sawmilling Committee's presentation of a technical session at the annual meeting in Seattle in 1955. The reaction of the committee was that inasmuch as both logging and milling are of such importance in the Pacific Northwest, we should definitely plan to sponsor such a session. The following topics or fields of interest were suggested:

1. Rubber tired prime movers.
2. Limitations and performance data on smaller size tractors associated with pre-logging and re-logging.
3. The Wyssen system—report on its operation and adaptation to heavy log operations.
4. Establishing coefficients of resistance—tree length and log lengths.

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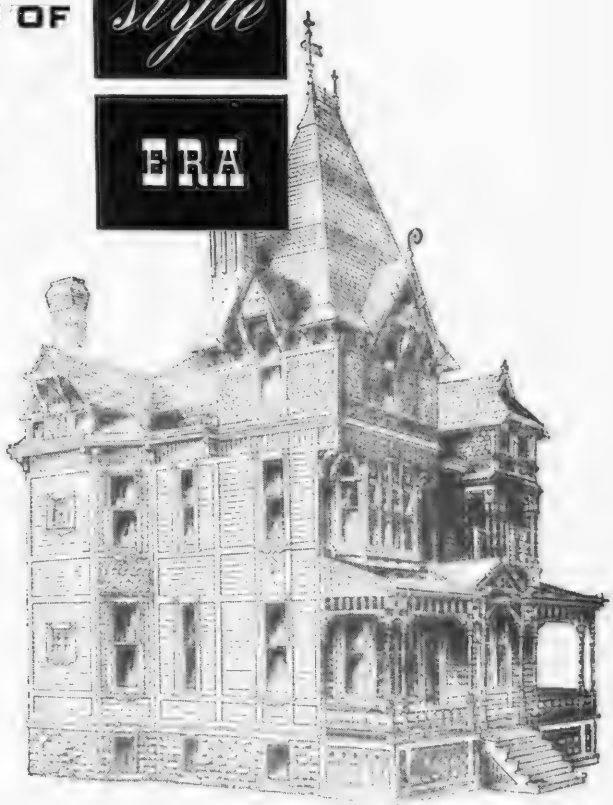

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5. Hardwood utilization in the west —alder, tanoak, madrone, Oregon white oak, Oregon maple.
6. Utilization of lodgepole pine—special logging and milling techniques.
7. The HIAB self loading crane.
8. Barking and chipping developments.

VENEER AND PLYWOOD—May 5—Chairman, Dr. Herbert O. Fleischer, U. S. Forest Products Laboratory

The first meeting of the Veneer and Plywood Subject Matter Committee was called to order by Chairman H. O. Fleischer at 2:30 P.M. Ten committee members and twenty-two visitors attended.

Chairman Fleischer reported that the organizing committee made up of himself, J. S. Bethel and M. B. Christian proposed the nomination of James R. Roberts for Senior Vice Chairman and C. H. White for Junior Vice Chairman. Then nominations were approved by those attending the meeting and were subject to approval by the Executive Board.

Chairman Fleischer recommended that a planning and policy subcommittee be appointed by the chairman, to prepare a report for the 1955 meeting on suggested activities, duties and projects that should be carried on by the veneer and plywood committee. A motion was made, seconded, and carried that such a subcommittee be authorized.

Next on the program was a panel discussion headed by Moderator E. H. Merritt who was introduced to the group by Chairman Fleischer along with other members of the panel, namely: John Butler, F. R. Eggers, J. H. Sweeney and C. H. White. The purpose of the panel discussion as outlined by Mr. Merritt was to present and discuss some of the key problems facing the veneer and plywood industry.

The first member of the panel to address the group was John Butler who pointed out that the veneer and plywood industry should: 1) Further the development of alcohol and heat resistant finishes and to improve paint finishes for plywood. 2) Conduct research to learn more about the acoustical properties of plywood. 3) Obtain more factual data on the bending of plywood. 4) Develop a statistical quality control program as related to quality tests of glue bonds.

Mr. Sweeney, the next panel member, discussed a problem of consumer complaints on the subject of severe surface checking in Fir plywood. Mr. Sweeney felt that some test might be developed that would enable the plywood distributor to eliminate those panels that would ultimately check after they are in the hands of consumers and in work. For hardwood plywood Mr. Sweeney felt that the industry should develop a product that will provide a truly flat, thin panel. To do this, it was suggested that new methods of laying plywood be investigated.

C. H. White next reviewed three problems which he felt were worthy of additional research. The problems listed by Mr. White were: 1) Develop the facts relating to the acoustical properties of plywood that may be used in the promotion of plywood and plywood products in the radio, television, high fidelity and architectural fields. 2) To continue existing research on the problems of stabilizing veneer so that it will not shrink, check, split or otherwise change from the time of cutting to its ultimate use in plywood: 3) To develop improved surface treatments for plywood in the form of press-cured finishes that will be alcohol and cigarette proof as well as fade resistant when exposed to light.

Mr. F. R. Eggers reported to the group that further research be carried

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out on: 1) The steaming of veneer logs. 2) The development of improved veneer splicing adhesives together with preventing dermatitis so commonly suffered by workers using the adhesives. 3) Veneer cutting and the waste problems resulting in rotary cutting.

The meeting was next open to discussion from the floor.

Mr. R. Casselman stated that he concurred with Mr. Eggers on the need for additional research on splicer adhesives.

Mr. Robert Larson reported on the need for further work on making flat, thin plywood, suggesting that the solution to the problem be found in new adhesives and the use of low moisture content veneers.

W. F. Hutchins brought out that the non-uniformity in the thickness of veneer created many problems as well as the lack of uniformity in moisture content of veneers. Mr. Hutchins further injected the need for research on the buckling of veneer in drying and the proper drying rates for veneer.

Chairman Fleischer stated that in his opinion studies on cutting veneer from species such as elm, aspen, beech and soft maple, be made and a market developed for these lesser used woods.

J. D. Ritchie suggested that much more work be done on building codes to help further the cause of plywood in building construction.

Mr. Van Epps stated that the radio and television laboratories have the necessary acoustical information on plywood which would eliminate the necessity for further research. Also Mr. Van Epps reported the problem of color stability of finishes has been at least partially solved by the introduction of new finishing materials.

Mr. Don Brouse suggested that more adequate testing procedures be developed for testing plywood bonds.

Messrs. Fleischer, Christian and Merritt next discussed the general use of moisture meters in determining the moisture content in veneer. After this discussion it was resolved that more research should be undertaken on the subject of drying veneers.

Mr. A. H. Bishop raised a question about the gluability of veneer dried at high temperatures (in excess of 300° F.) It was stated that high temperatures reduce the polarity of wood which might cause glue failure.

Mr. Christian asked if any work had been done in drying veneer with infrared lamps. None was reported except for small laboratory studies.

Mr. Don Miller next asked the group if any manufacturers of plywood had used tenderizers in conditioning veneer for plywood. Mr. Eggers reported that his firm had used a tenderizer to a limited extent.

The meeting was next turned over to Chairman Fleischer who summarized the highlights of the panel and floor discussions and thanked the members of the panel for generating a good deal of discussion at the meeting. Mr. Fleischer reported the Executive Board will consider a general session on veneers and plywood at the 1955 Annual Meeting in Seattle.

Mr. J. Bethel presented a motion that such a general session be held on veneers and plywood at the 1955 Annual Meeting. Mr. Merritt seconded the motion. In discussing the motion Mr. Eggers pointed out that since the meeting would be held on the West Coast it would be questionable if many of the hardwood people would attend and that the papers would probably be slanted to West Coast production problems and species.

Mr. Don Brouse stated that the veneer and plywood technical papers should be built on basic fundamentals which would be applicable to both hardwood and softwood problems and that fill-in material be injected with local interest problems.

Mr. Bethel's motion was carried following the preceding discussion.

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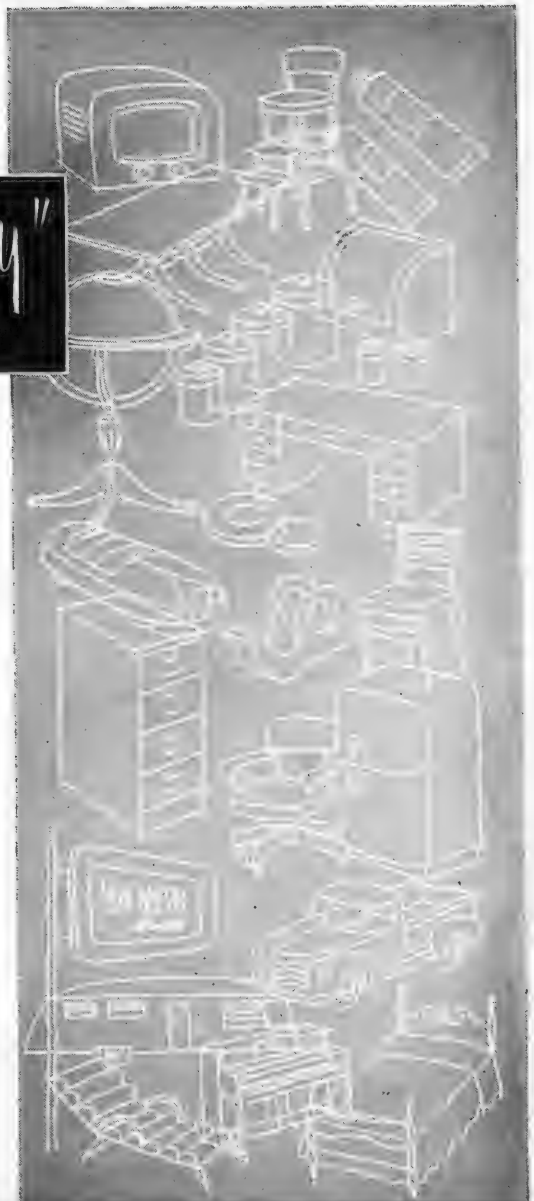

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Chairman Fleischer next announced that the Executive Board had asked each subject matter committee to present an industry review of developments that were related to the subject which, in the case of this committee, would be veneers and plywood.

The group was asked if they would favor making such a report that would ultimately be published in the Society Journal.

Mr. Sweeney presented a motion that a committee be appointed by Chairman Fleischer to prepare an industry review of veneers and plywood. The motion was seconded by Mr. Don Miller and carried.

MARKETING—May 5—Chairman, Philip H. W. Creden, Edward Hines Lumber Co.

The group reviewed first committee meetings and then listened to remarks by Chairman Creden on the possible scope of committee work and objectives.

John Reno presented "A Suggested Program for the Promotion of Lumber and Lumber Products." Discussion followed.

Marketing Committee policy was formulated and Creden outlined his paper "Promotion and Research—A Successful Marriage" which was later given at the general technical session.

The group then broke down the subject of marketing and aired the proposal to seek out case histories of marketing successes.

The assignment of marketing studies was given to several committee members.

MEETING OF COMBINED SUBJECT MATTER COMMITTEE CHAIRMEN

The following committees requested time for Technical Sessions at Seattle, next June 20, 23: Wood Drying; Wood Machining; Logging & Milling; Packaging; Education; Glues; Chemical Utilization (tentatively); Veneer and Plywood; Marketing (tentatively); Quality Control. No formal request came from Wood Finishing, and Wood Preservation.

The new Executive Board representative for the combined Committees was announced: Ralph H. Bescher, Koppers Company, Inc., (District Manager, Wood Preserving Division), Pittsburgh 19, Pennsylvania, will succeed M. B. Christian as coordinator of Subject Matter Committees.

E. G. Locke, Chairman of the Publications Committee, discussed the future development of "Annual Reports" by each Subject Matter Committee and their inclusion in an "Annual Report" number of the Journal. Each Committee chairman is responsible for an Annual Report objectively outlining progress in his field, to be submitted at the next Annual Meeting. For the first report the Committee can go back as far as it wishes in examining its field. In subsequent years the Report will take in the preceding 12 months only. No limit to length of report. Possible theme for next year's reports, "Trends in _____."

L. Patronsky suggested starting with a bibliography of the field as their first project. This suggestion was accepted. R. Bescher stated the purpose of the reports is to bring others up-to-date in fields in which they are not primarily engaged. He also suggested that the reports be written for the members at large and not for the experts, and said not to worry about being too all-inclusive at this time.

L. Carr proposed naming the general Chairman, "Coordinator" of Subject Matter Committees so as not to be confused with the Individual chairmen. He reviewed general procedure: a. Chairmen appointed for 2 years. b. Chairmen appoint or re-appoint their members annually. c. All members of FPRS are welcome—no closed meetings.

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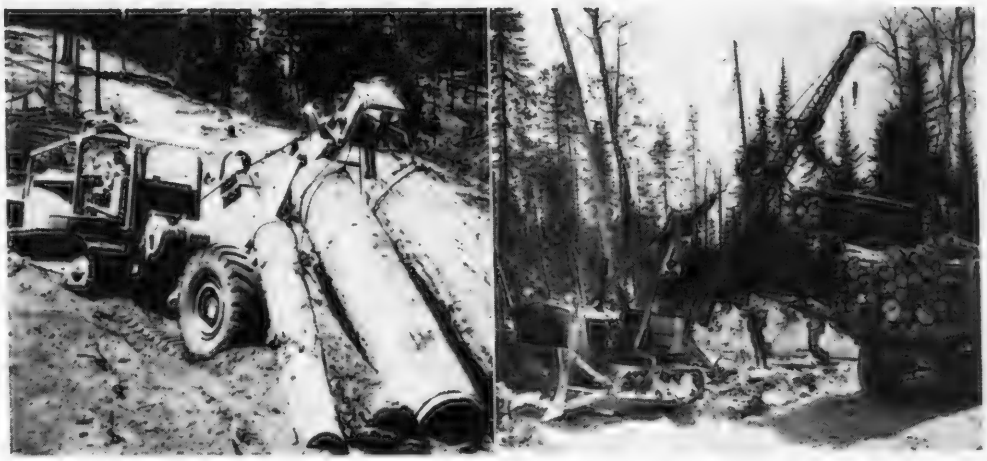

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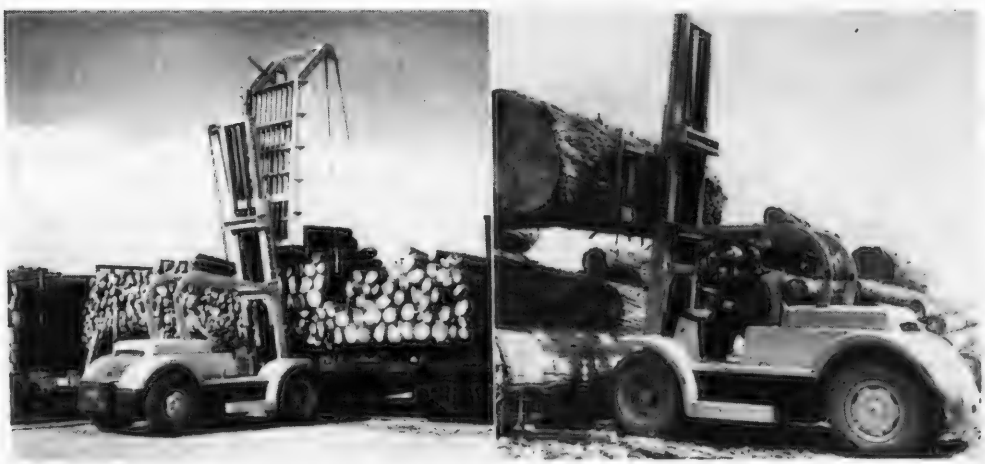

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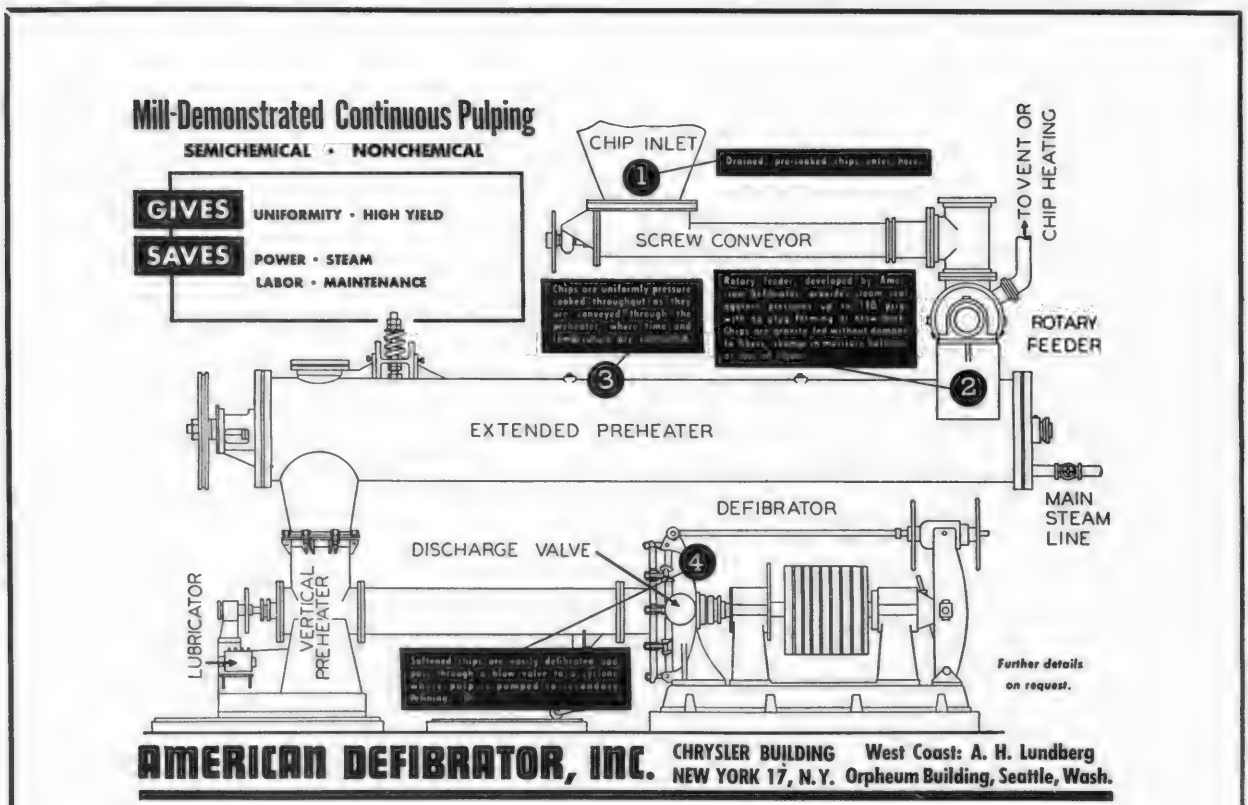

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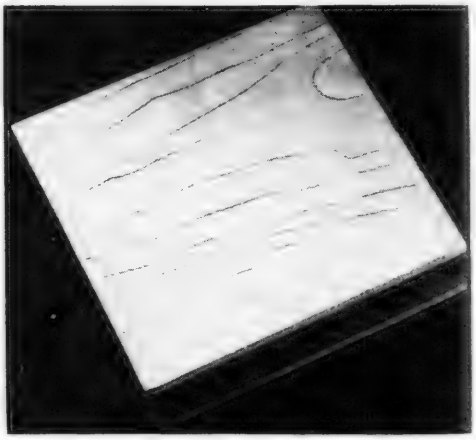

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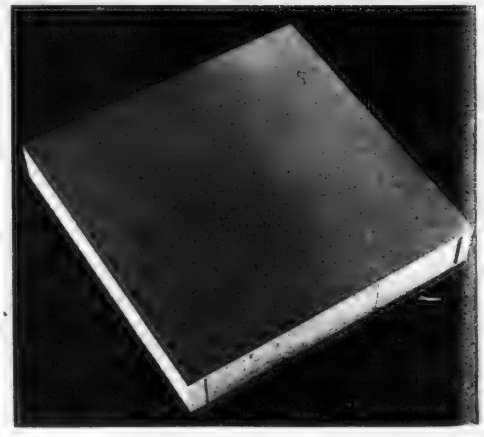

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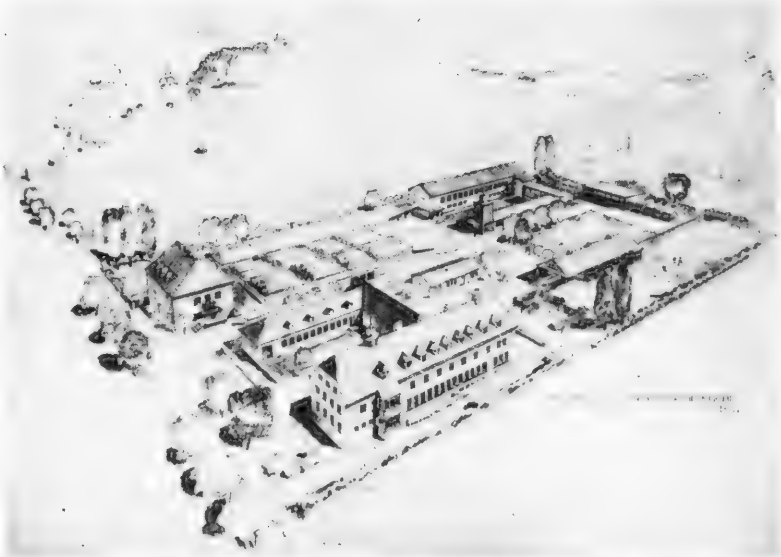
Around the World in Forest Products Research and Development by G. M. Hunt

Sawmill Workers Training and Research in Austria

THE LAND AREA of Austria is about 34,000 square miles, of which about 37 percent is timbered. There are over 6,000 sawmills in the country, providing full-time or part-time work to some 24,000 sawmill workers. Obviously, the average sawmill is a small affair, employing about 4 people. There are some large mills that have been modernized since the war with the loan of Marshall Plan funds and are staffed and equipped to manufacture lumber accurately and efficiently. There are many more 1-man or 2-man mills using inadequate and ancient equipment, frequently operating only part time, for the purpose of supplying local needs only. Many of the operators and workers in the small mills follow the methods handed down to them from previous generations, without much infiltration of new ideas.



The educational system of Austria provides vocational training through the apprenticeship method. Every boy, upon reaching the age of 14 must, with the help of his parents or advisors, choose his vocation and begin training for it, even though he may later progress on to higher education and a learned profession. The normal procedure is to apprentice the boy to a company or an individual who is practicing the vocation of his choice. Thus a boy who chooses to be a mason is apprenticed to a mason, one who chooses carpentry is apprenticed to a carpenter, and one who chooses sawmilling as his vocation starts to work as an apprentice in a sawmill. Each boy thus apprenticed works at his job for 3 years and is taught the vocation by his master. On one day of each week he goes to a special school for training in studies that his master is not equipped to teach and for special training in his craft. Instead of one day a week, his schooling may be concentrated into 8 weeks of continuous schooling each year in an apprentice school (Berufsschule). At the end of his 3-year apprenticeship, upon satisfactorily passing an examination, he becomes a journeyman craftsman and receives a certificate to that effect. There is only one apprentice school for sawmill workers in Austria, located at Kuchl near Salzburg, and boys are sent to it from all over the country for their 8-weeks annual schooling. The school operates throughout the year and thus can take care of a number of 8-week groups.

The foregoing apprenticeship and schooling program is the normal one and probably most boys follow it. They may, however, go to a full-time vocational school (Fachschule) for 3 years instead of becoming an apprentice. In order to do so, a boy must pass examinations and special tests, get certificates from the Labor Office, and have the consent of the Fachschule authorities. He then goes to the Fachschule for 3 years where he gets better schooling than the apprentices and is taught craftsmanship in several trades on a broader basis than the apprentices are taught. During each summer vacation period a boy in the Fachschule must work for 4 weeks at a trade, for experience. At the end of his 3 years, and after passing the necessary qualifying examination, he gets a certificate as a qualified worker, which allows him to work at a trade at normal wages, in the same way as a boy who has been taught by the apprenticeship method. He is better fitted for life and advancement, however, and has broader training than the boy who has had only the regular apprentice training. There was no full-time vocational school in Austria for sawmill workers up to the autumn of 1953, but at that time one was started at Kuchl, along with the apprentice school, which has been in operation in a small way for about 10 years.

The farsighted leaders of the sawmill industry have recognized the need for improved sawmill equipment and methods and for better training of sawmill workers and operators and have organized the School Association for Austrian Sawmill Workers (Schulverein der Sägewerker Osterreichs). The principal purpose of this Association is to support the sawmill schools at Kuchl, provide short courses for owners and operators, purchase and install experimental equipment for research to improve sawmilling machines and methods, and install a demonstration sawmill where the best methods and equipment for sawing, planing, drying, grading, and storing lumber may be demonstrated in actual practice. It is a very ambitious program but well worth a major effort to put into operation.

Thus far they have been able to expand and greatly improve the apprentice school for boys that was struggling along with inadequate facilities in 1946 and to get the full-time vocational school started. They have also conducted numerous short courses of a few days' duration for sawmill owners, operators, and foremen, to

bring them up to date on improved methods and equipment and stimulate their desire to improve their own operations. Both of the schools and the short courses are intended to be self-supporting through the fees charged to cover the cost of teaching and living expenses, but they do not pay for the buildings or for the equipment used.

The accompanying illustration is the architect's drawing of the completed institution at Kuchl.

The great problem of the school at Kuchl is financial. Money is scarce in Austria and interest rates on borrowed money are too high for any nonprofit organization. The plans for the institution are excellent and when completed will make it a center for sawmill research and training that will be outstanding and perhaps unequalled dustry through the School Association. anywhere. The buildings thus far constructed have been made possible through grants of Marshall Plan funds and contributions from the sawmill in- This Association, whose president and driving spirit is Ing. Josef Schleussner, a prominent sawmill owner, architect. and builder, is a subsidiary of the Austrian Sawmill Association (Verband der Sägeindustrie). The leading men of the latter association are Mr. Reisinger and Hofrat Dr. A. Ceschi. To these men and those associated with them belongs the credit for the excellent planning for the school and research center at Kuchl and for the progress that has been made to date against most discouraging obstacles Their persistence and drive must eventually bring the institution of their dreams into full reality and usefulness.

Abstracts of Important Wood Industry Publications

Physical and Mechanical Properties

Factors affecting the formation of heartwood in Douglas Fir *(Pseudotsuga taxifolia,* Britton). *Rep. B.C. Dep. Lds. For. 1952,* 1953 (36–8).

A study is in progress to determine whether it would be possible by silvicultural measures, to accelerate the formation of heartwood in Douglas Fir. The investigation is not complete, but preliminary results indicate that in all trees studied there is an intermediate zone between the heartwood and sapwood. which is visible to the naked eye. This intermediate zone generally extends from ground level to a point some distance above the top of the heartwood; its maximum width does not occur at the lower levels, but higher up the stem. The moisture content of this intermediate zone was appreciably lower than that of the sapwood, not only along the boundary of the heartwood but also above the top of the heartwood. [Forestry Abstracts, V. 15, No. 2]

Lawson, D. I., and Simms, D. L. The ignition of wood by radiation. *British Journal of Applied Physics, London* 3 (9), 1952 (288–92). 5 refs. X.

The minimum intensities of irradiation required to ignite wood, with and without the presence of a pilot flame, have been determined, and found to be approximately constant for nearly all six species tried. Empirical expressions have been obtained which relate the time taken to ignite with the intensity of irradiation and the oven-dry density of the wood for these two types of ignition. *Authors' summary.* [Forestry Abstracts, V. 15, No. 2]

Glues and Gluing

Vorreiter, L. Die Tropenfestigkeit von Leimverbindungen. Motivenbericht zum Normblattenwurf. [Resistance of glued joints in tropical conditions. A report for a suggested standard.] *Holz-Zbl.* 76 (143), 1950 (1613 . . . 1616). [G.] P.R.

Test 'climates' for glued specimens should have the following characteristics: (1) tropical rain-belt climate: 40° C. and 96% relative humidity; (2) tropical dry belt (*a*) day: 60° and 10% r.h., (*b*) night: 10° and 15% r.h. The use of two values of joint strength is suggested: the "hydro' strength for conditions in (1), and 'solar' strength for conditions in (2), the latter being determined in tests where a temperature of 60° (from visible, ultraviolet and infrared radiation) alternates with 10° every 12 hours. Besides these 2 strengths, the author suggests determining 4 others, viz.: (3) 'solhydro', combining the dry and wet tropical conditions, (4) 'arid tropical' (including attack by termites), (5) 'hydro tropical' (including attack by moulds and termites), and (6) 'all tropical' (comprising 1–5). The use of Spruce instead of Pine as test material is recommended. [Forestry Abstracts, V. 15, No. 2]

Guiher, J. K. The effect of alkyl-substituted phenolic adhesives on the bonding of Douglas Fir veneer. *Abstr. of thesis* in *Dissert. Abstr.* 13 (4), 1953 (475–6). [Michigan State College.] O.R.S.

The following main conclusions were reached from results of a series of experiments: (1) The shear strength of plywood bonded with different resins decreased in the order – m-cresol-formaldehyde, phenol-formaldehyde, m-ethylphenol-formaldehyde, and 3,5-dimethylphenol-formaldehyde resins. (2) Plywood strength increased with the increase in sp. gr. of veneer. (3) Plywood strength increased with the addition of walnut-shell flour in amounts of 10–20% of the content of resin solids. (4) Maximum plywood strength was reached in 9–16 days after bonding. [Forestry Abstracts, V. 15, No. 2]

Gefahrt, J. Elektrische Wider standsverleimung. [Gluing with electrical resistance heating.] *Holz* (10–12), 1952 (246–9; 275–7; 294 5). 6 refs. [G.] P.R.

Discuss the efficiency of resistance heating, form and size of heating elements, the source of current, and possibilities of use. [Forestry Abstracts V. 15, No. 2]

Edwards, N. C. High-frequency heating applied to the manufacture of case ends. *For. Prod. News Lett C.S.I.R.O. Aust.* No. 194, 195 (1–2).

Describes briefly an experimental press designed for continuous edge gluing of pairs of boards to produce panels 14¼ × 8¾ × ⅝ in. The best gluing rate was 6 joints/min., representing an energy dissipation of 450 watt sec./sq. in. of glueline. It is estimated from the results that equipment using dielectric heating and costing roughly £2000 will have the same output as a mechanical jointer costing about £12,000. [Forestry Abstracts, V. 15, No. 2]

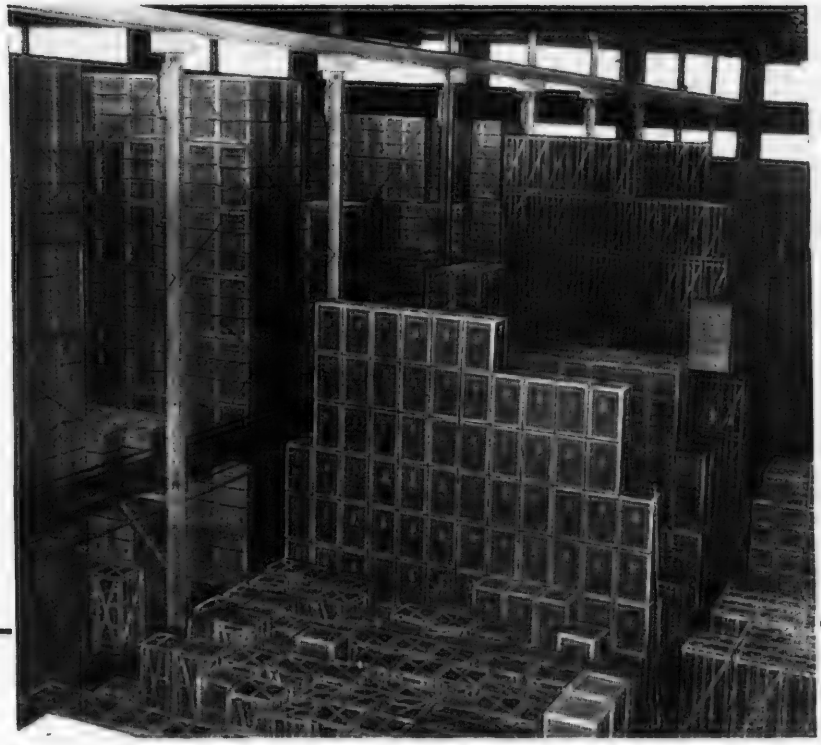
Veneer and Plywood

Lutz, J. Cutting and drying properties of Redwood vtneer. *Veneers & Plyw.* 47 (8), 1953 (8–9, 30–1). P.R.

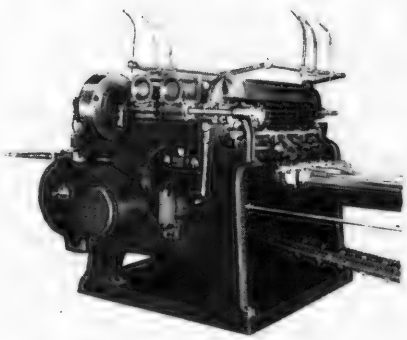
Presents some results of tests made at Madison, and information gained from industrial observation, relating to the selection and preparation of veneer logs of *Sequoia sempervirens,* veneer cutting, drying, yield gluability. [Forestry Abstracts, V. 15, No. 2]

Sconce, R. E. Paper, Fir veneer 'wedded' to form containerboard. *Veneers & Plyw.* 47 (5), 1953 (10 32–4). P.R.

Discusses the merits of 'Ply-Veneer', a new product consisting of kraft containerboard (made from Douglas Fir chips) and a specially processed [Douglas] Fir veneer. [Forestry Abstracts, V. 15, No. 2]



A mountain of DIFFERENT containers . . .



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In operation, it produces 1200 lineal inches of cleated box panels per minute. Actual installations with a crew of 8 people are producing what formerly required 29 people and a machinery investment costing twice as much!

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FPRS News-Digest, Continued

BUSINESS OUTLOOK

'53. The plentiful supply of mortgage money has inspired a home-building boom which is eclipsing the '53 performance . . . easier terms on consumer installment loans kicked consumer spending to an all-time high in the second quarter of this year, and the trend is still upward.

FURNITURE SALES GAIN Orders climbed 4% over July activity to equal year-ago figures for the first time in 1954. Shipments mounted 32% over the month-earlier mark to score the largest July-August increase in three years and came within 3% of the August '53 level. For the year to date, shipments are 13% short of comparable '53 volume.

SOFTWOOD LUMBER PRICES FIRM—Despite the recent prolonged strike, mills in the Douglas-fir region report prices above pre-strike levels. Several factors: log stocks are about depleted, big Government orders are awaiting early delivery, mills not affected by the strike now cutting back operations as the larger plants come back into the market. At last report production had climbed to 75% of normal output and is expected to accelerate.

—Veneer Newsletter.

NEW CONSTRUCTION SOARS—The value of new construction work put in place increased seasonally in July to reach a new all-time monthly high of $3.5 billion. Recent new gains in private housing starts plus a record volume of new construction contracts during the first half of the year virtually assure a continuation of this unprecedented rate of construction activity during the next succeeding months.

Private construction set a new monthly record in July, expanding somewhat more than seasonally to $2,377 million. The value of residential building put in place rose to $1,237 million, 10 percent above the year-ago level and higher than any month since October 1950. Public construction outlays went 3 percent over July a year ago.

—Construction and Building Materials.

INDUSTRY NEWS

NLMA Annual Meeting

How the lumber industry can boost sales through more aggressive merchandising and greater product publicity will be the theme of the 1954 annual meeting of the National Lumber Manufacturers Association, Executive Vice President Leo V. Bodine announced today. The meeting will be held Nov. 8–10, at the Shoreham Hotel, Washington, D. C.

About 100 of the nation's leading lumber producers, including FPRS National President Lester J. Carr, will attend the meeting to map strategy for promoting greater use of lumber in the year ahead. Special sessions will be devoted to reviewing and planning the association's public relations and trade promotion programs. Mr. Bodine, members of the NLMA staff and Standing Committees will explain what the association has done in the past 12 months to spur sales of lumber and wood products.

A feature of the meeting will be the premier of a new color motion picture, "Engineered Timber Construction," released by the Timber Engineering Company. Another highlight will be a panel discussion on merchandising programs of the lumber industry, wood's role in the construction picture, and the architect's interest in wood.

Architectural Woodwork Institute Meets at Chicago

A.W.I.'s second annual convention was held at the LaSalle Hotel, Chicago, Ill., on October 15th and 16th. President Charles A. Rinehimer discussed the effect the 257-member Institute's first year's program on the architectural profession.

European Wood Preservers Meet

On September 15, 16, 17 the annual congress of the Western-European Institute for Wood Preservation was held in Naples, Italy, according to Sec. A. B. van Hengel, The Hague, Netherlands. Representatives of government authorities, scientific institutes, and private industry in the field of wood preservation of twelve countries were present. Progress reports on the preservation of timber with creosote oil and with salts, and statistics and service records on the use of impregnated wood were made. Lengthening of the serviceable life of wooden railway sleepers, and impregnation of building timber were also discussed.

Small Sawmill Performance Standards Project

A meeting of the A.S.M.E. Committee B-66 will be held at the Engineering Societies' Building in New York City Nov. 29, according to Thomas D. Perry, Moorestown, N.J., Chairman. This committee is attempting to formulate a performance standard, confined to allowable variations in thicknesses produced for small sawmills throughout the country. It will hear two reports. One, a draft of a proposed performance standard by a committee task force; and two, a progress report by the FPRS Logging and Milling Committee headed by Fred C. Simmons, Upper Darby, Pa., on the compilation of a "Small Sawmill Operator's Handbook" which is currently in rough draft form.

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FPRS News-Digest, Continued

New Hydraulic Slab De-Barker Successful

Wholesale recovery of pulpwood chips from both large and small mill slabs is promised by the successful operation of the South's first "slab concentration yard" by Clancy Forest Products, Inc., at Decatur, Ala. The heart of the new plant is a hydraulic slab de-barker designed by Clancy and constructed by Jackson Industries, Birmingham, Ala. "Efficiency of the Machine," Mr. Clancy points out, "enables us to pay $8 a cord for barky slabs and edgings delivered on our yard. That's sufficient incentive for mills as much as 75 miles away to offer us their full production of pine slabs. Available slab supply will more than meet the needs of our weekly production of 500 cords of chips."

Forestry Students Receive TECO Certificates

Three outstanding forestry school students from Michigan, Indiana, and North Carolina were awarded special certificates recently to mark their successful completion of a ten-week course in wood technology and utilization at the Washington, D. C. laboratory of the Timber Engineering Co. The three students, who received their TECO training under $500 scholarships awarded by NLMA are Ulric S. Lindholm, Michigan State; Hugh D. Angleton, Purdue; and Robert B. Jordan III, North Carolina State.

Pulp Companies Employ 1,515 Foresters

Pulp companies in the U. S. now employ an average of nine foresters for each of the 171 firms using pulpwood, according to a study made by the American Pulpwood Association. More than half, 868, are in forest management compared with 263 so engaged seven years before. According to W. S. Bromley, APA Exec. Sec., "This comparison shows that pulp companies' employment of professional foresters for management of woodland increased 300 percent between 1945 and 1952."

SOCIETY NEWS

FPRS Executive Board Meeting In Denver Sept. 20, 21

The FPRS Executive Board met recently in Denver to review among many subjects, contract bids and final drawings and specifications for the proposed new FPRS executive office building to be erected in Madison, Wisconsin. The building will embody the latest in wood construction and design throughout. Also agreed upon was a general plan for enabling various segments of the wood industries to contribute materials for the building. (In a near future issue of the News–Digest an artists sketch and floor plans of the building will be shown). The Board also selected Buffalo, New York, as the site for the 1957 National Meeting with close cooperation between the Eastern Canadian and Northeast Sections.

New FPRS Publication Price List Available

"How to Order FPRS Publications", a newly printed FPRS catalog of publications. Covers the four types of FPRS publications, namely, the Journal of the FPRS, the Annual Proceedings numbers, the Wood Technology Series booklets, and many of the Individual Reprints. This up-to-date catalog lists every article and contents of every publication since 1947. Write Box 2010 University Station, Madison, Wis.

President Carr on Swing of FPRS Meetings

Lester J. Carr, FPRS President and general manager, L. J. Carr Co., Sacramento, Calif., has started on an extensive fall tour of nine FPRS and other association meetings. Carr, FPRS' "travelingest" president, plans to attend at least one of each of the meetings of the 13 FPRS sections during his year in office. On this swing he will attend the Carolinas–Chesapeake meeting in Asheville, N.C., on Oct. 11 and 12; the Ohio Valley Section meeting on Oct. 14 and 15 in Louisville, Ky.; the Pacific Northwest meeting at Corvallis, Ore., on Oct. 25 and 26; the Northern California meeting at Chico, Calif., on Oct. 28; the Upper Mississippi Valley meeting at St. Paul, Minn., on Nov. 2 and 3; and the Northeast meeting on Nov. 4 and 5 in New York City.

FPRS Salutes Its Newest Supporting Member

We are proud to announce that The Dean Company, T. J. Connelly, President, 666 Lake Shore Drive, Chicago, Ill., recently became a supporting member of the FPRS. The Dean Company manufactures fine veneers and lumber. Ted Connelly has long been active in FPRS events in the Midwest Section.

1955 "Wood and Wood Products" Award Announced

With the U. S. economy geared toward a decade or more of unprecedented demand for products of our forests, the need for more and better technically-trained men grows in importance with each passing year.

One of the more positive programs in this direction has been the Wood and Wood Products Award, sponsored since its inception in 1948, by Vance Publishing Company, Chicago. Each year this publisher offers $500 to be awarded to the two students making the most significant contributions to the industry. The 1955 Awards will again be presented in conjunction with FPRS Ninth National Meeting at Seattle Washington, June 20–23, 1955. The winner of the outstanding graduate paper will receive $350; and the winner of the undergraduate competition $150. The former will also be encouraged to present his paper at the meeting.

Subjects may be of any choosing which makes a fundamental or practical contribution to the industry, in the way of research, development, production, utilization or marketing. Papers should be based on work completed subsequent to 1953–54 academic year.

Entries should be submitted prior to May 10, 1955, through the Executive Office of the Society, Box 2010, University Station, Madison 5, Wisconsin, for consideration by the Education Committee, administrators of the Award. Chairman for the graduate and undergraduate judging committees are, respectively, Robert R. Blumenstein, Laboratory Manager, Timber Engineering Company, Washington, D.C.; and Prof. Everett Ellis, School of Forestry, University of Idaho, Moscow, Idaho.

Wood and Wood Products Award winners in recent years have included a number of men who have since achieved considerable distinction in the industry. Among these are Nicholas V. Poletika, Timber Engineering Company, S. B. Preston, on the staff of the University of Michigan, and most recently, Charles R. Morschauser, on the staff of the Oregon Forest Products Laboratory, Corvallis, Ore.

Automation to Feature Northeast Section Meet Nov. 4, 5

Executives, key production and research men of wood products industries are now registering for the fall meeting of the Northeast Section, Forest Products Research Society which is being held at the Prince George Hotel in New York City, November 4th and 5th, according to chairman C. R. Lockard. The

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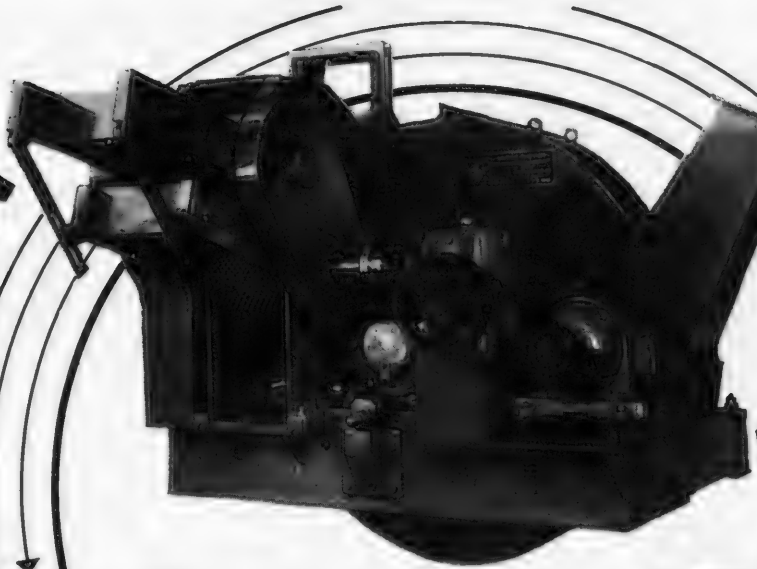

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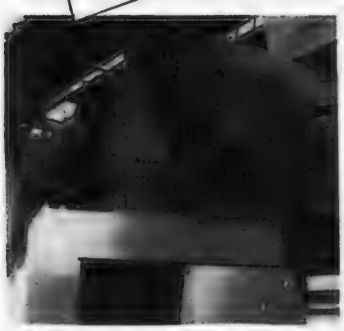

MURCO 75" Mechanical Feed Wastewood Chipper installed at Allison Lumber Co., Bellamy, Alabama

Produce quality specification size pulp wood chips from sawmill waste, slabs and edgings with the new MURCO Mechanical Wastewood Chipper. The design of this machine incorporates the performance proved features of standard MURCO Round Wood Chippers plus a newly designed mechanically operated spout for feeding sawmill waste wood into the disc knives at a controlled rate of speed that assures utilization of all the wood yet holds slivers and odd sized chips to minimum.

Check these design features -

- Mechanical spout feed mechanism speed is synchronized to the speed of the disc to assure uniform chip length.
- A specially designed wood holding device installed after the feed rolls holds the wood against the disc knives reducing slivers to a minimum.
- Spout can be arranged for either horizontal or angle feed at operator's option.
- Drive can be either electric motor or Diesel engine. If the main drive is electric motor, then the feed mechanism is driven by a small reversible electric motor. If Diesel engine operated, then the feed mechanism is driven with reversible power takeoff.
- Chipper can be equipped with chip blower housing for pneumatic chip conveying if desired.

FOR COMPLETE PROPOSAL. GIVE US THIS INFORMATION:

1. Species of wood to be chipped.
2. Number of cords per hour.
3. Dimensions of largest slab.
4. Will chips be conveyed pneumatically.
5. Type of drive desired — Diesel or electric.

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new science of automation (Wood on the Move) will be featured at this meeting as part of a technical program developed upon the theme —What's News In Wood.

Two all-day sessions will be held Thursday and Friday, beginning at 9:00 a.m. and ending at 5:00 p.m. The program will consist of four sessions devoted to: What Works With Wood, What's New In Wood Processing, What's Being Done With Wood, and Wood Problems. Discussion groups will be headed by experts in their respective fields for the discussion of wood industry problems common to the Northeast.

Subjects at the technical sessions will include: Particle Board; New Aspects of Non-Destructive Testing; Quality Control of Veneer; Problems in Fabricating Helicopter Rotor Blades; Laminated Cross-Arms; New Developments in Wood Preservation; Alkali and Acid Resistant Impregnated Wood; Chem Dry Process (for finish coatings); Phenol-Formaldehyde Wood Coating Resins; Automatic Control Techniques in Processing Wood Products; Application of Cutter Speeds; Custom Millwork; Study of Cross Sections of Finished Furniture Panels; and other subjects to be announced.

Attendance at this two-day meeting is not confined to FPRS members and anyone interested is invited to attend. Reservations may be made through Wm. J. Delmhorst, Delmhorst Instrument Co., Boonton, N.J., or in person at the Prince George Hotel, East 28th Street, New York City any time after 7:00 p.m. Wednesday, November 3rd.

SHORT COURSES

Furniture Finishing Short Course, Nov. 8–12, High Point, N. C.

Sponsored by N. C. State College, the course will be conducted by the School of Forestry, the Department of Industrial Engineering, and the Southern Furniture Manufacturers Association at the Lilly Co. plant. Designed for furniture finishing room foremen, their assistants and supervisors, the course will include the rundown on newest materials, spraying techniques, equipment, and application methods. Write to Eugene Starnes, Box 5125, State College Station, Raleigh, N.C.

Scenes from "This Was Logging"—a New Pictorial Book

Trailer railroad. No cars used on this Forks Logging Company rail line.

Down cedar 1380 years old over which firs grew for 560 years.

This Was Logging. A suberb 50 year photographic study of logging life and times in the Pacific Northwest from the 8,000 print record of Darius Kinsey with a biographical story of this famed timber photographer by Ralph W. Andrews. Shown in more than 200 finely detailed pictures are many views never before made public . . . of horse and oxen logging, inclines, trestles, home-made tractors and early trucks, steam saws, homesteads . . . people as they lived and worked in the timber from 1896 to 1940. Price $8.50 per copy. Superior Publishing Co., P. O. Box 2190, Seattle 11, Washington.

TECO Course in Adhesives, December 6–10

The five-day course is conducted for management and production personnel in furniture, woodworking, structural and marine laminating, and other wood-using industries. For information write R. C. Cranch, Timber Engineering Co., 1319 18th Street, N.W. Washington 6, D. C.

N. C. State Kiln Drying Course, Dec. 6–11

E. F. Rasmussen, Forest Products Lab., kiln engineer, Madison, Wis., will be the chief instructor for a seven-day kiln drying course at North Carolina State College Dec. 6–11. Enrollment fee, $50. Reservations may be made through Prof. Roy M. Carter, School of Forestry, N. C. State College, Raleigh, N. C.

New York State Offers Kiln Course

Dr. Harold B. Gatslick, announces a dry kiln operation short course will be conducted by the College of Forestry in Syracuse, January 24–29. Write Prof. Russell C. Deckert, Industry Service Representative, State University College of Forestry, Syracuse 10, N. Y.

Midwest Section Meets

The Midwest Section held its fall meeting at the Forest Products Laboratory at Madison, Wis., Sept. 23, 24. A highlight of the meeting occurred when Midwest Chairman Wayne Lewis presented a $1,000

Midwest Section group tours prefab plant.

check to Dr. J. Alfred Hall, North-Central Board Member towards the construction of the FPRS executive office building.

Six speakers on the program discussed marketing, new products, finishing, quality control, and conveyors. One of the speakers, T. S. Mallinson, London, England, presented "A Briton's Appraisal of the Timber Trade and Industry in the United States." Mallinson, after a year in this country, was impressed with the amount of lumber that has been moved through the "do-it-yourself" promotion. In the afternoon of the 24th the group toured the grounds of Erdman & Associates, Madison home builders and prefabricators, who are currently making two prefab home units per day for distribution in their "U-Form-It" sales package.

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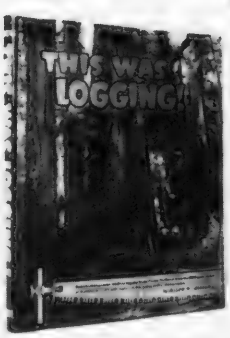

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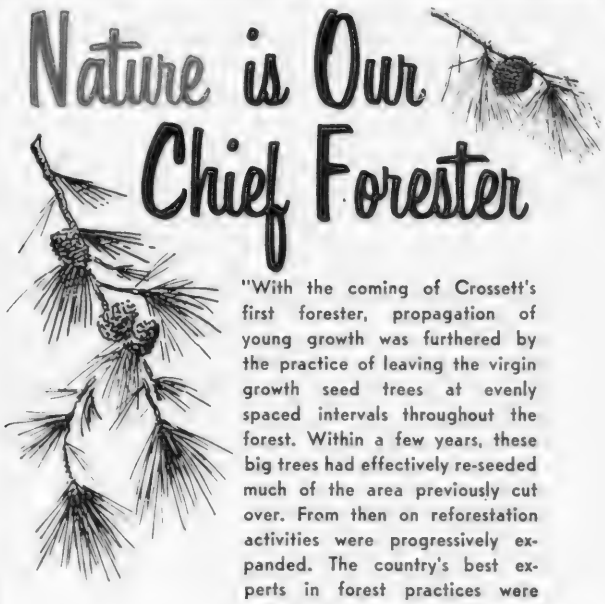

"With the coming of Crossett's first forester, propagation of young growth was furthered by the practice of leaving the virgin growth seed trees at evenly spaced intervals throughout the forest. Within a few years, these big trees had effectively re-seeded much of the area previously cut over. From then on reforestation activities were progressively expanded. The country's best experts in forest practices were called in. From these consultations came Crossett's modern system of selective cutting and sustained yield which adequately provide raw material needed for continuous operations."

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Crossett, Arkansas

New Midwest officers meet Speaker Mallinson.

Chairman Wayne Lewis presents $1000 check.

Midwest Speakers: Haile

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NEW PUBLICATIONS

Gluing Characteristics of Various Eastern Canadian Wood Species. E. G. Bergin. Results of studies to determine the inherent gluing characteristics of the more important Eastern Canadian species. Available: Forest Products Lab. of Canada, Ottawa, Ont.

Studies on Smooth and Cork-bark Alpine Fir. 1. Fibre Length Comparisons. R. W. Kennedy, J. W. Wilson. These studies were undertaken to investigate the pulp quality of wood from these two forms of Abies Lasiocarpa as represented by tracheid length. Available: Research Paper No. 6, Faculty of Forestry, University of British Columbia, Vancouver, B. C.

Estimating Volume from Stump Measurements. Kenneth L. Quigley. Technical paper No. 142. Foresters sometimes have to estimate the volume of timber harvested from the stumps that remain after logging. In order to test this stump method of estimating volume of timber harvested, CSFES has been tallying stumps on field sample plots for several years in statewide surveys of forest resources. Available: Central States Forest Experiment Station, Columbus, Ohio.

Marketing Woodlot Products in the State of Washington. George Stenzel. Covers: place of the small woodlot owner in the forest economy of the state, where to get advice on forest management and forest products marketing, forest laws woodlot owners should know, specifications and markets, forest products with limited marketing possibilities, summary of marketing methods, truck loadings and road classifications, and log scale and associated tables. Available: Institute of Forest Products, 303 Anderson Hall, Univ. of Washington, Seattle 5, Wash.

Volume 3 of The Yale Conservation Studies. This volume contains articles of current interest on forestry in Japan, water pollution problems, and the national parks, among others. The articles are written by students and graduates of the Yale Conservation Program. Available: Yale Conservation Program, 77 Prospect St., New Haven, Conn. Price $1.00.

Effectiveness of Flooring Nails Versus Toothed Fastener. No. 16. E. George Stern. The tests performed during the study were of a fully comparative nature. They provide information on the immediate effectiveness of these fasteners as well as on their service performance, since some of the tests were made to simulate accelerated service conditions. Available: Virginia Polytechnic Institute, Blacksburg, Va.

Wire Skidding: Wood Transportation By Gravity Over a Suspended Wire. A. Koroleff and R. D. Collier. This book summaries the results of ten years of experimental work on wire skidding. This gravity transport technique and the equipment employed, is the result of a concerted effort to develop a relatively simple and economical method of forwarding wood down steep slopes from stump to haul road or waterway. This 137-page illustrated book may be purchased from the McGill University Book Store, 3480 University St., Montreal, P. Q. at $2.00 per copy.

The following publications are available from the Forest Products Laboratory, Madison 5, Wis.

Variations in Fibril Angles in Slash Pine. Charlotte H. Hiller (Report No. 2003). This study on slash pine was undertaken (a) to bring

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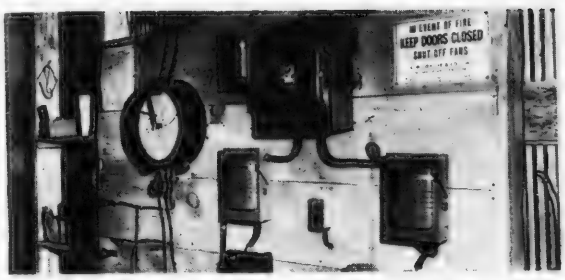

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Whatever the specific problem of lumber seasoning, there's a solution in some type of Lovsted "Direct-Flo" Kiln. These units are without question the most efficient kilns in operation today. They embody such specialized features as reversible circulation with fans positioned to create uniform drying with lowest possible power input per cubic foot of air produced.

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FPRS News-Digest, Continued

further evidence on the influence of age and ring width on the size of fibril angles, and (b) to determine whether the data indicate that the fibril angles may be also controlled by genetic factors.

Color Tests for Differentiating Heartwood and Sapwood of Certain Oaks, Pines, and Douglas-Fir. (Tech. Note No. 253). Three chemical color tests have been developed by which sapwood and heartwood of certain oaks, pines, and Douglas-Fir can be readily differentiated. They consist of the application of a small amount of chemical solution across the grain of the wood.

Fire Research and Results at the Forest Products Laboratory. T. R. Truax. (Report No. 1999). Surveys briefly some of the fire research that has been done at the Forest Products Laboratory, summarizes the more important results, and refers to some of the important work of others.

Inside Wood—A Short Trip Into the Interior for the Layman. F. J. Champion. (Report No. 1995). This report explains in non-technical terms the structure and chemical substances which make up wood.

Electrical Moisture Meters for Wood. W. L. James. (Report No. 1660). This report lists the makers of electrical moisture meters and explains the operation of resistance-type and capacity and radio-frequency power-loss types of moisture meters. These instruments are designed to provide a quick, easy, and non-destructive quantitative test for moisture in wood. Instruments now available are being used successfully for moisture control in many forest products industries.

The Role of Inspection in Wood Ladder Safety. L. J. Markwardt. (Report No. 1994). Examines the structure of wood and its characteristics required for good ladder construction. Describes proper inspection and maintenance procedures for safe usage of ladders.

NAMES IN THE NEWS

To Attend Latin American Meeting

Dr. J. A. Hall, director of the U. S. Forest Products Laboratory, Madison, Wis., and FPRS North-Central National Executive Board Member, and G. H. Chidester, Lab. pulp and paper expert, left October 13th for Buenos Aires, where they will attend a meeting of 100 foreign experts on the pulp and paper industry, sponsored by the E.C.A., F.A.O., and the U.N. to help further the development of pulp and paper industries in Latin America.

National Adhesives Appoints Rep.

In the South East area National Adhesives has appointed Robert L Smith as representative, with headquarters in Hickory, N. C.

Norton to Head FPRS Employment

Prof. Newell A. Norton, head Department of Wood Utilization Pennsylvania State University, State College, Pa., has been appointed chairman of the recently formed National Employment Committee for the FPRS.

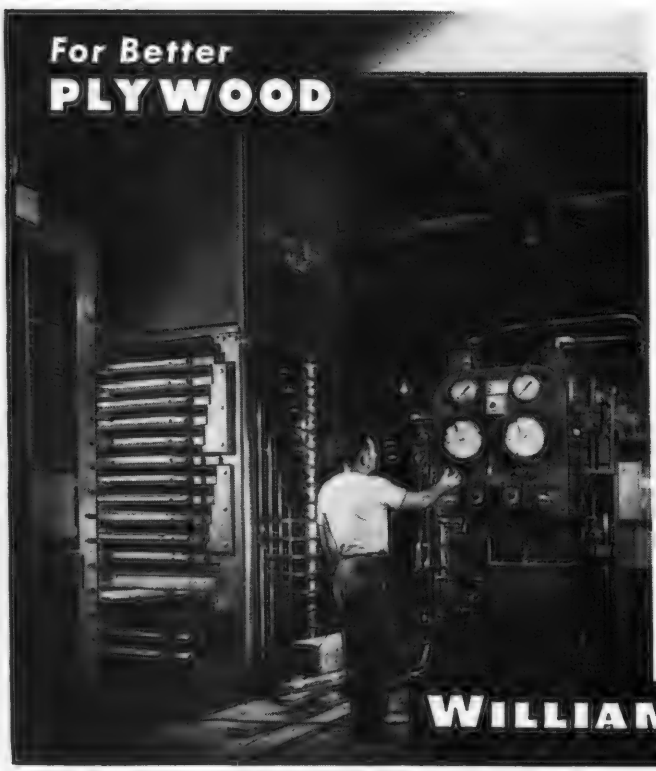
Exec. Sec. Attends Iowa State 50th Anniversary

Frank J. Rovsek, FPRS Executive Secretary, attended the two-day 50th Anniversary observance of the Department of Forestry, Iowa State College at Ames, October 15 and 16

NEW PRODUCTS, LITERATURE AND NEWS

Raybond Laminating Press

New brochures are available describing Raybond Edge-Gluing Machine



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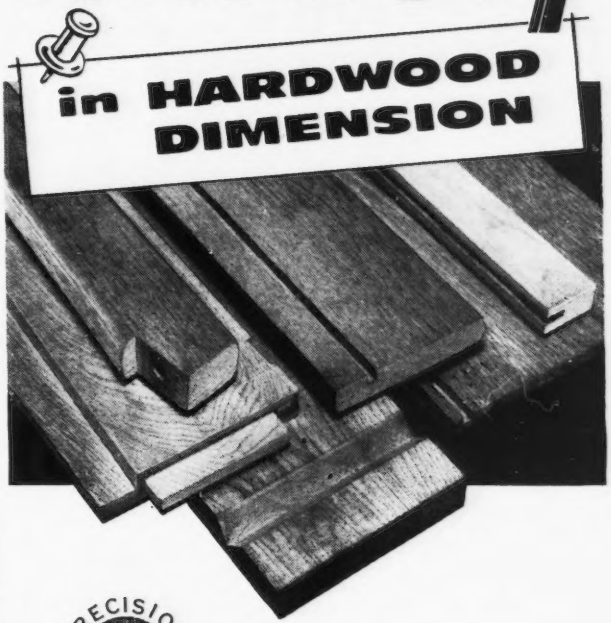

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If you have a production problem, we believe we can help you. For quick service on *Precision Wood Parts* for furniture, cabinets and fine boxes; mouldings, etc., write or phone our Asheville office.

HARCO

WILLIAMS-BROWNELL Inc.
ASHEVILLE, NORTH CAROLINA
ESTABLISHED 1905

lumber laminating press. Method of operation, specifications are included. Write Electronic Heating Corp., 66 Needham St., Newton Highlands, Mass.

New Thermosetting Adhesives

A new series of Thermosetting Adhesives that have two to seven days stable working periods coupled with fast curing hot or cold press has been announced by National Adhesives, 270 Madison Ave., New York 16, N. Y. Available in emulsion or solution form these adhesives eliminate catalyst addition and proportioning, previously the most critical step in the preparation of thermosetting adhesives. Known as Duro–Lok, these products are offered as emulsions and solutions. Paste forms are also available.

Sales Concern to Market Laminated Products

National distribution of glued-laminated arches, beams and other construction timber items produced by the American Fabricators division of Bellingham Shipyards Company will be handled by Mackintosh & Truman, Inc., wholesale forest products sales organization. The arrangement allows the American Fabricators management to concentrate on production and technical matters by using a nation-wide sales organization to handle marketing of the glued-laminated products to the construction industry, Fred W. Gottschalk, Seattle, president of Mackintosh & Truman, explains.

Wilco Steam Saver Unit

A bulletin describing new economies in steam operations with the Wilco-Stansbury Steam Saver is announced by Wilco Machine Works, 1301 N. Hollywood, Memphis, Tennessee. A completely closed hot condensate system, the unit has demonstrated proven economies in fuel and steam consumption and improved capacity in veneer dryers, elimination of "cold corners" in hot plate presses, and shorter cycles in rendering and other cookers.

FPRS SCOREBOARD
by Bob Smith

A new membership "key" promotion idea has been submitted by Paul Graham, the Membership Chairman of the Northeast Section. This idea calls for three new membership brochures stressing that through the FPRS lies the "key" to improving your personal growth and education in wood products, as well as moving the industry forward generally. The leaflets will be written for the general voting and associate member prospect, the student, and the delinquent member. We hope to have these brochures available for use shortly.

Speaking of delinquent members, there are a large number of members who have not as yet paid their 1954 dues. This is after the third consecutive invoicing, and from where I sit it looks like these members will be lost in a few weeks, if we don't get on the ball. As many as 150–200 members could be dropped. We are, of course, constantly gaining new members but a sizeable loss like this is detrimental to the Society as a whole. If you haven't paid your dues yet, won't you send in your check now? Thanks.

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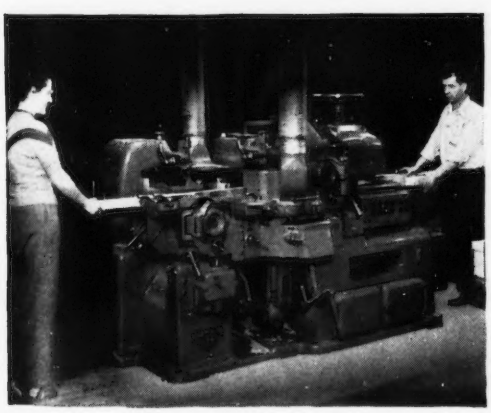

IMPERIAL FURNITURE COMPANY
Imperial Tables
GRAND RAPIDS·2·MICHIGAN

March 18, 1953

Mattison Machine Works
Rockford, Illinois

Gentlemen:

Early this year, we installed one of your No. 276 Heavy-Duty High Speed Electric Moulders. We thought you might like to know how we are getting along with this machine.

Here at Imperial, we manufacture a complete line of high grade tables, and the moulder work must be as nearly perfect as possible to reduce our sanding and fitting operations. With the addition of this Mattison No. 276, the quality of our moulded work has improved substantially while our costs have gone down.

Our operators find this Mattison No. 276 very easy to set up, due to the accessibility of all the adjustments and controls. Vertical and cross adjustments of the cutterheads are made positively and quickly, and the hand locking wrenches which are attached to the machine simplify setting of the guides. Another feature is that it "stays put", which is no doubt due to the rigid construction, precision manufacture, and advanced engineering design. The outboard bearings eliminate vibration in heavy cuts, and we believe that any high speed moulder spindle should have an outboard bearing.

We are confident that this machine will continue to perform efficiently for a great many years.

Yours very truly,

IMPERIAL FURNITURE COMPANY

A. F. Christy

A. F. Christy
Plant Manager

- Imperial Furniture Company's reputation for building a high quality line of tables is in a good measure due to precise fabrication methods which insures consistently accurate results and proper fitting of all parts. Mr. A. F. Christy, Plant Manager of Imperial, has been around the woodworking industry for a good many years and knows what he wants and has to have in the way of production and accurate results. The above letter telling of his experience with the Mattison 276 Moulder is an example of what this machine is doing for a good many others. For complete information on the Mattison 276 High Speed Electric Moulder, ask us to send you our latest free circular.

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The special rifle-bored heating plate will amaze you. — For smaller units no pit is required and low pressure steam will give you fast curing.

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